CUK-H04398-1-257391

GSI. 40
1,030

©

BULLETINS
OF THE
GEOLOGICAL SURVEY OF INDIA

SERIES B—ENGINEERING GEOLOGY AND GROUNDWATER

NO. 9—GEOLOGY AND GROUNDWATER RESOURCES OF THE ANJAR-KHEDOI REGION, EASTERN KUTCH, WITH PARTICULAR REFERENCE TO THE KANDLA PORT WATER-SUPPLY

By

G. C. Taylor, Jr., *U. S. Geological Survey*
AND
B. D. Pathak, *Geological Survey of India*

1

Published by order of the Government of India.

PRINTED IN INDIA, BY THE MANAGER, GOVERNMENT OF INDIA PRESS, CALCUTTA,
AND PUBLISHED BY THE MANAGER OF PUBLICATIONS, CIVIL LINES, DELHI, 1960.

Price : Rs. 11 or 17 sh. 6d.

RECENT PUBLICATIONS OF THE GEOLOGICAL SURVEY OF INDIA

RECORDS :

	Rs.	A.	P.
Vol. 85, Pt. 1—General Report for 1951	4	8	0
„ 85, Pt. 2—Mineral Production of the Indian Union during 1951	4	8	0
„ 85, Pt. 3—Papers	4	8	0
„ 85, Pt. 4—Papers	4	8	0
„ 86, Pt. 1—General Report for 1952	4	8	0
„ 86, Pt. 2—Mineral Production of the Indian Union during 1952	4	8	0
„ 87, Pt. 1—General Report for 1953	4	8	0
„ 87, Pt. 2—Mineral Production of the Indian Union during 1953	4	8	0
„ 88, Pt. 1—General Report for 1954	4	8	0
„ 88, Pt. 2—Mineral Production of the Indian Union during 1954	4	8	0

BULLETINS :

Series A—Economic Geology:

	Rs.	A.	P.
No. 13—Clay-shale deposits suitable for use in the manufacture of cement at Sindri, Manbhum, Bihar, by D. R. S. Mehta	1	0	0
No. 14—The Manganese-ore deposits in Udaipur and Banswara, Rajasthan, by B. C. Roy	1	12	0
No. 15—The Manganese-ore deposits of Panch Mahals and Baroda districts, Bombay State, by B. C. Roy	3	4	0
No. 16—High Grade Limestone Deposits, Dehra Dun—Mussoorie Area, by D. R. S. Mehta, B. R. Narayanamurthy & A. S. Narasimhan	7	0	0
No. 17—The Manganese-ore Deposits near Joida, North Kanara District, by B. C. Roy and Y. S. Sahasrabudhe	2	8	0

Series B—Engineering Geology and Groundwater:

	Rs.	A.	P.
No. 8—Geology and Groundwater in Deccan Traps and Application of Geophysical Methods, by B. G. Deshpande and S. N. Sen Gupta	0	14	0
No. 10—A Study of Groundwater in the City of Bikaner, Rajasthan, by D. N. Sett	1	12	0
No. 11—Groundwater Resources of the Andhra State with special reference to Rayalaseema districts, by M. S. Balasundaram and V. Subramanayam	1	14	0
No. 12—Geological Notes on the Central Railway Tunnels on the Western Ghats, India, by B. C. Roy	2	12	0

MEMOIRS :

	Rs.	A.	P.
Vol. 82—Geology and Gem-Stones of the Mogok Stone Tract, Burma, by L. A. N. Iyer	4	12	0
„ 83 Petrology of Indian Coals, by P. N. Ganju	5	0	0
„ 84, Pt. 1—A Revision of the Geology and Coal Resources of the Raniganj Coalfield, by D. R. S. Mehta	7	12	0
„ 84, Pt. 2—A Revision of the Geology and Coal Resources of the Jharia Coalfield, by D. R. S. Mehta and B. R. Narayanamurthy	9	4	0

[Continued on inner side of the back cover.]

5

CALCUTTA UNIVERSITY
CENTRAL LIBRARY

GS I. 40
1,030

©

BULLETINS
OF THE
GEOLOGICAL SURVEY OF INDIA

SERIES B—ENGINEERING GEOLOGY AND GROUNDWATER

NO. 9—GEOLOGY AND GROUNDWATER RESOURCES OF THE ANJAR-KHEDOI REGION, EASTERN KUTCH, WITH PARTICULAR REFERENCE TO THE KANDLA PORT WATER-SUPPLY

By

G. C. TAYLOR, Jr., *U. S. Geological Survey*
AND
B. D. PATHAK, *Geological Survey of India*

1

Published by order of the Government of India.

PRINTED IN INDIA, BY THE MANAGER, GOVERNMENT OF INDIA PRESS, CALCUTTA,
AND PUBLISHED BY THE MANAGER OF PUBLICATIONS, CIVIL LINES, DELHI, 1960.

257391.

GEOLOGY AND GROUND WATER RESOURCES OF THE ANJAR-KHEDOI REGION, EASTERN KUTCH, WITH PARTICULAR REFERENCE TO THE KANDLA PORT WATER-SUPPLY

By

G. C. Taylor, Jr., *U. S. Geological Survey*[*]

and

B. D. Pathak, *Geological Survey of India*

(With Plates 1 to 8)

CONTENTS

Pages.

Summary VII

Introduction 1

  Location and Extent of the Area 1

  Scope and Purpose of Investigation 1

  Acknowledgements 2

Climate 3

Physiography 6

Drainage 10

Geology 12

  Sequence and General Features of the Rocks 12

  Geologic History and Stratigraphic Relations of the Rocks . . . 13

  Physical Character and Water-bearing Properties of the Rocks . . . 16

    Quarternary System 16

      Alluvium 16

    Tertiary System 17

      Pliocene (?) 17

        Manchar Series 17

          Physical Character 17

          Water-bearing Properties 22

---

[*] On deputation to the Geological Survey of India under the United States Technical Co-operation (Point IV) Programme.

CONTENTS—*contd.*

PAGES.

Eocene (?) 24

Laterite 24

Cretaceous and Tertiary Systems 27

Deccan Trap 27

Lava flows 27

Physical Character 27

Water-bearing Properties 31

Dykes and Sills 32

Cretaceous System 35

Upper Bhuj Series 35

Physical Character 35

Water-bearing Properties 37

Cretaceous and Jurassic Systems 40

Lower Bhuj Series 40

Physical Character 40

Water-bearing Properties 42

Jurassic System 43

Katrol Series 43

Geologic Structure 44

General Features 44

Folds 45

Faults 47

Epochs of Deformation 48

GROUNDWATER IN THE BHUJ SERIES 49

Water in Upper Bhuj Aquifers 49

Form and Depth of the Water Table 49

Fluctuations of Groundwater Level 50

Causes of Fluctuations 50

Seasonal Fluctuations related to Infiltration from Rainfall and Stream run-off. 51

Fluctuations related to Evaporation and Transpiration . . . 57

Fluctuations related to Pumping from Wells 59

CONTENTS—*contd.*

PAGES.

Fluctuations related to Changes in Atmospheric Pressure 62
Source and Replenishment of the Groundwater 64
Movement of the Groundwater 66
Discharge of the Groundwater 68
Present Utilisation of Groundwater from Upper Bhuj Aquifers . . 70
Perennial Yield from Upper Bhuj Aquifers 74
Water in lower Bhuj Aquifers 76
Occurrence of the Groundwater 76
Present utilisation of Groundwater from Lower Bhuj Aquifers . . 77
CHEMICAL QUALITY OF THE GROUNDWATER 78
General Features 78
Quality Character with respect to Use for Irrigation and Public Supplies . 79
Distribution of Salinity in the Shallow Groundwater of the Bhuj Series . 82
Salinity in Deep Aquifers of the Bhuj Series 83
Seasonal Changes in Groundwater Salinity 84
EXPLORATORY DRILLING FOR WATER IN THE ANJOR-KHEDOI REGION . . 85
GROUNDWATER CONDITIONS IN THE VIRI AREA 90
Drainage and Topography 90
Geologic Features 90
Groundwater in Upper Bhuj Aquifers of the Viri Area 91
Source, Movement and Disposal of the Groundwater 91
Present Utilisation of the Groundwater 93
Pumping Tests at the Viri Tubewells 93
Chemical Quality of the Groundwater in the Viri Area . . . . . [illegible]
Perennial Yield of Groundwater in the Viri Area 98
FUTURE DEVELOPMENT OF GROUNDWATER 98
REFERENCES 102
APPENDICES 104
Appendix 1.—Results of chemical analyses for chlorides in water from shallow wells in the Anjar-Khedoi region. (Analyses by Sindhu Resettlement Corporation Laboratory, Gandhidham.) 104
„ 2.—Complete chemical analyses of water from shallow wells in the Anjar-Khedoi region. (Analyses by Geological Survey of India Laboratory, Calcutta.) 108

CONTENTS—*contd.*

PAGES.

Appendix 3.—Partial chemical analyses of waters from shallow wells in the Anjar-Khedoi region. (Analyses by Geological Survey of India Laboratory, Calcutta.) . 109

„ 4.—Chemical analyses of water from shallow wells near Viri, Shinaya and Kidana. (Analyses by Sindhu Resettlement Corporation, Gandhidham.) . 110

„ 5.—Partial chemical analyses of waters from deep exploratory borings in the Anjar-Khedoi region. (Analyses by the Sindhu Resettlement Laboratory, Gandhidham and the Imperial Chemical Industries Laboratory, Ahmedabad.) 112

„ 6.—Partial chemical analyses of waters from production tubewells in the Viri area, February 1951 to May 1954. (Analyses by Sindhu Resettlement Corporation Laboratory, Gandhidham.) . . 117

„ 7.—Results of periodic chemical analyses of chlorides in water samples from production tubewells in the Viri area, February 1951-May 1954. (Analyses by Sindhu Resettlement Corporation Laboratory, Gandhidham.) 120

„ 8.—Logs of deep exploratory borings in the Anjar-Khedoi region. 124

„ 9.—Logs of production tubewells in the Anjar-Khedoi region. 134

„ 10.—Mechanical analyses of formation samples from deep exploratory borings and production tubewells in the Anjar-Khedoi region. 137

„ 11.—Capacity tests of water-bearing zones in exploratory borings in the Anjar-Khedoi region. . 148

„ 12.—Measurements of depth to water in observation wells in the Anjar-Khedoi region, 1951-54. . . 155

„ 13.—Pumpage from production tubewells in the Viri area, November 1951 to May 1954. . . . 197

14.—Hydrologic data from wells in the Anjar-Khedoi region. 204

ILLUSTRATIONS

FIGURES

Figure 1. Index map of Western India showing the location of the Anjar-Khedoi region, eastern Kutch. . . . vi

„ 2. Hydrographs of three shallow wells in or near irrigated tracts showing seasonal fluctuations of water levels, 1951-52. 53

„ 3. Hydrographs of four shallow wells remote from irrigated tracts showing seasonal fluctuations of water levels 1951-52. 54

„ 4. Hydrographs of three deep tubewells and one shallow dug well in the Viri area showing fluctuations of water levels through three one-year cycles, 1951-54. . . 55

„ 5. Hydrographs of two wells in the Viri area showing typical daily fluctuations of water levels, June-July 1951. 58

„ 6. Hydrograph of well 4, Khedoi irrigated tract, showing typical daily fluctuations of water level, May-June 1951. 60

„ 7. Hydrograph of well A6, Viri area, showing typical daily fluctuations of water level, December 1951. . 61

CONTENTS—*contd.*

FIGURES—*contd.*

PAGES.

Figure 8. Hydrograph of well 6, Nagalpur irrigated tract, showing typical daily fluctuations and barograph at Gandhidham, June-July 1951. 3

„ 9. Hydrographs of four deep tubewells and one shallow dug well in the Viri area showing fluctuations of water levels during pumping of well A5, October-November 1951 94

PLATES

Plate 1. Geologic Map of the Anjar-Khedoi region, eastern Kutch showing the locations of wells and springs also contours of the water table in May 1952

„ 1A. Geologic cross-sections of the Anjar-Khedoi region, eastern Kutch.

„ 2. Map showing the form and slope of the water table in the shallow groundwater of the Upper Bhuj series, Anjar-Khedoi region, eastern Kutch in June 1951.

„ 3. Map showing the form and slope of the water table in the shallow groundwater of the Upper Bhuj series, Anjar-Khedoi region, eastern Kutch in October-November 1951.

„ 4. Map showing the distribution of chlorides in the shallow groundwater of the Bhuj series, Anjar-Khedoi region, eastern Kutch.

„ 5. Map of the Viri area, Anjar-Khedoi region, eastern Kutch showing the form and slope of the water table in the shallow groundwater of the Upper Bhuj series—June 1951.

„ 6. Map of the Viri area, Anjar-Khedoi region, eastern Kutch showing the form and slope of the water table in the shallow groundwater of the Upper Bhuj series—October-November 1951.

„ 7. Map of the Viri area, Anjar-Khedoi region, eastern Kutch showing the form and slope of the water table in the shallow groundwater of the Upper Bhuj series—May 1952.

„ 8. Map of the Viri area, Anjar-Khedoi region, eastern Kutch showing the distribution of chlorides in the shallow groundwater of the Upper Bhuj series—June 1951.

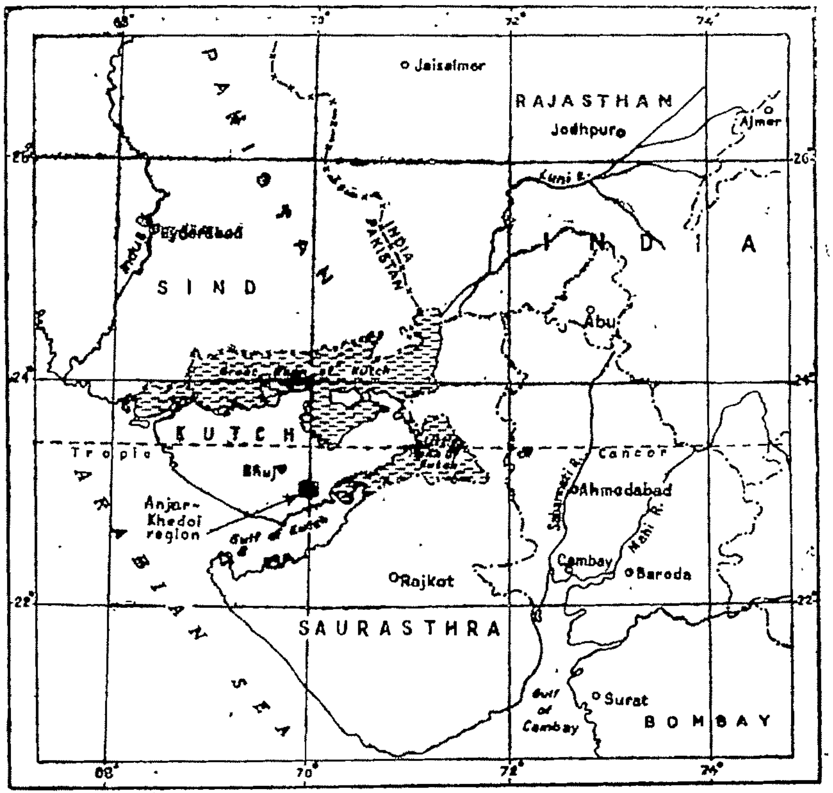


Figure 1. INDEX MAP OF WESTERN INDIA SHOWING THE LOCATION OF THE ANJAR-KHEDOI REGION, EASTERN KUTCH.

GEOLOGY AND GROUNDWATER CONDITIONS OF THE SHAHABAD-PIPLI-LADWA AREA, KARNAL DISTRICT, PUNJAB.

By

A. B. Biswas, M.Sc., *Geologist,*
Geological Survey of India.

CONTENTS

PAGES.

Introduction 1
Location and General Features 1
Scope and nature of investigation 2
Climate 3
Topography and Drainage 8
Geology 9
Occurrence of Groundwater 15
General Features 15
Shallow zones tapped by open wells 16
Deeper zones tapped by tubewells 17
Chemical Quality of Groundwater 19
Shallow zones tapped by open wells 19
Deeper zones tapped by tubewells 22
Conclusions 22
Suggestions for Further Work 23
Bibliography 24

APPENDICES

1. Selected logs of tubewells drilled for the Punjab State in the Shahabad-Pipli-Ladwa area, Karnal district, by the French Group of Drilling Companies, 1954-55.
2. Locality index.
3. Hydrologic data on shallow dug wells in the Shahabad-Pipli-Ladwa area, Karnal district, Punjab.

ILLUSTRATIONS

PLATE 1.—Sketch map showing the location of wells in the Shahabad-Pipli-Ladwa area, Karnal district, Punjab.

PLATE 2.—Rainfall records for stations at Karnal and Thanesar, for the period 1900-50.

Fig. 1.—Annual precipitation.

Fig. 2.—Residual mass curve of Precipitation for station at Thanesar.

PLATE 3.—North-South Generalised Geological Section A-A′, in the Shahabad-Pipli-Ladwa area.

PLATE 4.—East-West Generalised Geological Section B-B′, in the Shahabad-Pipli-Ladwa area.

PLATE 5.—Map showing the areal distribution of chloride in the shallow groundwater of the Shahabad-Pipli-Ladwa area.

PLATE 6.—Map showing the areal distribution of bicarbonate in the shallow groundwater of the Shahabad-Pipli-Ladwa area.

PLATE 7.—Map showing the areal distribution of total hardness in the shallow groundwater of the Shahabad-Pipli-Ladwa area.

GEOLOGY AND SAMPLING OF THE MAJHGAWAN DIAMOND DEPOSIT, PANNA DISTRICT, MADHYA PRADESH

BY

S. M. MATHUR, M.Sc., *Geologist*

AND

H. N. SINGH, M.Sc., *Geologist,*
Geological Survey of India.

CONTENTS

CHAPTER PAGES

PART I—GENERAL

I. INTRODUCTION 1

PART II—GEOLOGY

II. REGIONAL GEOLOGY AND CONTACT EFFECTS
  Kaimur Sandstone 4
  Contact Rock 5
  Discussion of Contact Effects 6
III. THE VOLCANIC PIPE .
  Surface plan of the Pipe 6
  Alluvium 7
  Shales 7
  Age 8
IV. THE ULTRAMAFIC PIPE ROCK
  "Agglomeratic tuff" 8
  Calcite veins in "Agglomeratic tuff" 10
  Weathered tuffaceous material 10
  Dark coloured volcanic rock 10
  Relationship of various types 11
  Chemical composition 11
  Nomenclature 14
V. INCLUSIONS
  Cognate Xenoliths 14
  Accidental Inclusions 15

CHAPTER PART III—SAMPLING PAGES.

VI. GENERAL REMARKS ON SAMPLING

Shafting Procedure 16
Sampling Procedure 16
Treatment and Milling 17
Security 17
Progress of Sampling 17

VII. SAMPLING RESULTS

Agglomeratic tuff samples 20
Tuffaceous and shaly samples 22
Alluvial Overburden samples 23
Sample from Balakhadan 24

PART IV—CONCLUSIONS AND RECOMMENDATIONS

VIII. CONCLUSIONS ON SAMPLING

Quality of Diamonds 26
Distribution of Diamonds 26
Reserves of Diamonds 27

IX. RECOMMENDATIONS 27

APPENDICES—

A. Drilling results 30
B. Water supply 36
C. Description of sampling shafts 40
D. Description of experimental trenches . . . 44
E. Detailed shaft-wise production 46

LIST OF REFERENCES 59

LIST OF PLATES

Pl. 1	. . . .	A 3-carat diamond (circled) in the matrix of agglomeratic tuff. Balakhadan pit, Majhgawan mine.
Pl. 2,	fig. 1 . . .	Cognate inclusion of serpentinous rock in agglomeratic tuff.
	fig. 2 . . .	Inclusion of a pebble (broken) of hematite in agglomeratic tuff.
Pl	fig. 1 . . .	View of a shaft entrance. In the absence of mechanical gear, haulage is done by manual labour.
	fig. 2	Inside view of a shaft showing timber lining and ladderway.
Pl 4,	fig. 1 . . .	Head-frame of a shaft in refilled ground, which collapsed at the onset of rains.
	fig. 2 . . .	A general view of Balakhadan, which is the only working quarry.

Pl. 5, fig. 1 . . . . Jaw crusher (top) and roll crusher (bottom). The ore is being transported by a relay of women workers. The other workmen are machine attendants.

fig. 2 . . . . The hopper into which the ore is discharged by the bucket elevator is at top left. The workmen are pushing the ore down the chutes into washing pans.

Pl. 6 . . . . . Geological map of the Majhgawan Diamond Deposit, Scale 1″—100 ft.

Pl. 7 . . . . . Section along A_1-A_2 and B_1-B_2. Scale 1″—100 ft.

Pl. 8 . . . . . Plan of the Majhgawan Diamond Mine showing scheme of sampling. Scale 1″—150 ft.

ABSTRACT

Under an overburden of alluvium, a yellow "agglomeratic tuff" is found in the central portion of the Majhgawan pipe area, while a weathered tuffaceous rock often mixed with shale is found in its narrow western portion and along the periphery. Most of the diamonds were found in the former, while a few were also recovered from the latter. A dark coloured ultramafic volcanic rock, having the same mineralogical composition and texture as the "agglomeratic tuff" was found underneath the former in some boreholes put down through the pipe. The diamantiferous nature of this rock is still to be ascertained by sampling.

The pipe was sampled by putting down shafts at regular intervals of 250 ft. Twenty shafts totalling 704 ft. were excavated, out of which nine reached "agglomeratic tuff", five went through disintegrated tuffaceous materials, five were in sandstone and shales while one was not completed owing to collapse. The treatment of the nine "agglomeratic tuff" samples (40 tons from each shaft) gave an average of 9·41 carats valued at approximately Rs. 1,400 per 100 loads (or 11·76 carats valued at Rs. 1,749 per 100 tons). Some tuffaceous samples yielded an average of 0·40 carats valued at approximately Rs. 17 per 100 loads (or 0·50 carats valued at Rs. 21 per 100 tons).

SUMMARY

The present report describes the availability of groundwater supply in the Anjar-Khedoi region primary for the Kandla Port development of the Government of India and the Gandhidham township of the Sindhu Resettlement Corporation and secondarily for irrigation. The field investigation on which this report is based was carried on over a 2-year period extending from June 1950 to June 1952 with continuing hydrologic observations through June 1954. Included in the investigation were geologic mapping and delimitation of the principal aquifers of the region, preparation of seasonal water-table maps, detailed inventories of existing wells and springs to determine the extent of present groundwater use for irrigation, observations of significant water-table fluctuations, preparation of salinity maps and geologic and hydrologic observations at 8 deep exploratory borings.

The Anjar-Khedoi region as described in this report lies in eastern Kutch between latitudes 23° 10′ 00″ and 23° 00′ 00″ north and longitudes 69° 52′ 30″ and 70° 07′ 30″ east of Greenwich (Figure 1). The region covers about 184 square miles and lies in a belt of semi-arid, low-latitude steppes. The mean annual rainfall is about 14 inches most of which falls between late June and late September. The region contains several upland or low hilly tracts interspersed with lowlands which are partly cultivated through irrigation from groundwater sources. Elevations in the region range from about 10 to 548 feet above sea level. The streams of the region are all of ephemeral character and carry water only in response to monsoon run-off.

Included among the rocks of the Anjar-Khedoi region are continental and marine sediments of Mesozoic, Tertiary and Quaternary age and volcanic rocks of late Mesozoic to early Tertiary age. The oldest exposed rocks are shales with minor sandstones of the Upper Jurassic Katrol series. Overlying the Katrol are sediments of the Bhuj series which comprise a lower unit of alternating non-marine sandstones and shales and an upper unit of massive current-bedded sandstones.

The age of the Bhuj series may range from Upper Jurassic through Lower Cretaceous. Lava flows of the Deccan trap which is of Upper Cretaceous to Eocene age rest directly on the Bhuj series but are absent in the northwest part of the map area probably owing to removal by erosion. An extensive horizon of laterite developed at the top of the Deccan-trap is placed in the Post-Deccan Eocene. Mottled sandstone, fossiliferous sandstone, clay shale and conglomerate which overlie the laterite and the Deccan trap are referred to the late Tertiary Manchhar series and are probably Pliocene in age. Thin discontinuous bands of alluvium along the channels of the larger ephemeral streams of the region are considered to be of Quaternary age.

Locally along the channels of the larger ephemeral streams of the region, the sand and gravel facies of the alluvium are water-bearing and yield small supplies of brackish water to shallow dug wells. The sandstones and conglomerates of the Manchhar series yield meagre to small supplies of brackish water to wells. In places, however, the water is salty. Very meagre supplies of brackish to salty water are obtained from shallow wells in the laterite in a few places but generally the laterite is above the zone of saturation. The Deccan trap generally yields small to moderate supplies of good water to wells less than 75 feet deep but locally the water is brackish. The soft friable sandstones of the Upper Bhuj series form the most productive aquifers in the Anjar-Khedoi region as well as in other parts of eastern Kutch. These

aquifers yield moderate to abundant supplies of good to brackish water to wells and springs. The thicker sandstone members of the Lower Bhuj series also yield moderate supplies of good to brackish water to wells and springs. Sediments of Katrol series yield only meagre supplies of brackish to salty water to wells.

Probably in conjunction with Middle Miocene and subsequent orogenic movements of the Himalayan region and of Sind and Baluchistan the rocks of Kutch were compressed into folds along three major anticlinal axes separated by broad synclinal depressions. The axes of the folds trend generally northwest-southeast in western Kutch but swing to an east-west trend in the central and eastern parts of the state. The great anticlinal structure of the Chauduva (Katrol) Hills in central Kutch extends eastward into the Anjar-Khedoi region as the Nigal dome and dies out in the smaller anticlinal folds of the Ratnal Hills, Samparda ridge, the Mita *nadi* upland and the Shinaya Hills. (Plate 1.)

The groundwater body in sandstone aquifers of the Upper Bhuj series is the most productive and most extensively developed in the Anjar-Khedoi region. The upper surface of this groundwater body is marked by a water-table whose form and slope is shown by contours for May 1952, June 1951 and October-November 1951 in Plates 1 to 3, respectively. As indicated by these maps the water-table slopes in a general easterly direction from an altitude of about 300 feet near Loharia to 180 feet near Anjar. The water-table crops out at the land surface in springs near Viri and Khedoi. However, among 10 irrigated tracts the median depth to water ranged from 20 to 70 feet below land surface as based on water-level measurements made in late 1951 and early 1952.

Based on observational data collected during the present investigation, water levels in wells tapping Upper Bhuj aquifers are known to fluctuate in response to infiltration from rainfall and from run-off in stream channels, discharge by evaporation and transpiration, discharge by pumping from wells and changes in atmospheric pressure. In addition fluctuations not distinguished may occur as a result of other causes.

Replenishment to the groundwater body in the Upper Bhuj series takes place by direct infiltration from rain which falls on the land surface, by infiltration from ephemeral streams while in spate, by return seepage from irrigation, by groundwater inflow from areas outside the Anjar-Khedoi region and by underground leakage from Lower Bhuj into Upper Bhuj aquifers. Of these recharge sources rainfall penetration is probably the most important in the region. Recharge by rainfall penetration to the groundwater body may range from as little as 5 per cent. of the annual rainfall in dry years to 25 per cent. in years of average rainfall and may be as much as 40 per cent. in exceptionally wet years.

As shown by the water-table contours of Plates 1, 2 and 3, the groundwater movement in Upper Bhuj aquifers was generally in an easterly direction in most of the Anjar-Khedoi region with gradients of about 17 to 30 feet to the mile. Local depressions or troughs in the water-table developed near Khedoi Mota, Khamra, Bhadroi, Sidungra, Nagalpur and Anjar owing to withdrawals of water from wells for irrigation.

The discharge of groundwater from Upper Bhuj aquifers of the Anjar-Khedoi region takes place by evaporation and transpiration of groundwater plants, by the flow of springs and by withdrawals from wells for irrigation and public supplies. The combined natural and artificial discharge of groundwater from Upper Bhuj aquifers of the

Anjar-Khedoi region by evaporation, transpiration, spring flow and withdrawals for irrigation was of the order of 14,685 acre-feet in 1951.

A detailed inventory during 1951-52 indicated there were some 660 wells of dug or dug and bored construction in the Anjar-Khedoi region that tap water in Upper Bhuj aquifers at depths ranging from 15 to 247 feet below land surface. In addition there were 5 tube wells in the Viri area from 155 to 228 feet deep that are used for the Gandhidham-Kandla Port Public Water Supply. Currently (May 1954), 3 of the tube wells are being pumped alternately in pairs at 8 to 9 hours per day each and pumpage has ranged from 504,000 to 700,000 Imperial gallons per day. Mechanical pumps have also been used to an increasing degree in dug irrigation wells of the region. In 1951-52 there were some 78 pumps, all of horizontal centrifugal type in operation with yields ranging from about 50 to 380 Imperial gallons per minute. However, the age-old combination "mote" (leather bag) and bullocks is still the most important method for drawing water from wells for irrigation. The draft from individual wells by this method ranges from about 8,000 to 36,000 gallons a day with one to three motes working simultaneously in the same well. During 1951 the total draft for irrigation was at an average rate of 12,645 acre-feet per year or an average of about 44·2 acre-feet per day during the irrigation season.

Rough calculations indicate that the annual recharge from all sources to Upper Bhuj aquifers within the Anjar-Khedoi region may range in magnitude from about 3,000 acre-feet in dry years to as much as 18,000 acre-feet in wet years. In addition groundwater is transmitted into the region through Upper Bhuj aquifers from the area to the west of Loharia and by leakage from Lower Bhuj aquifers. The long-term safe yield from Upper Bhuj aquifers of the region is estimated to be of the order of 10,000 to 12,000 acre-feet per year. The current (1951-54) rate of withdrawal for irrigation and for the Gandhidham-Kandla Port Water Supply is roughly equivalent to and even slightly exceeds the estimated safe yield. Therefore any additional draft on the groundwater body would necessarily be taken from storage and could not be indefinitely sustained without detriment to existing wells.

The chemical quality of a water is a factor of paramount importance in its utilization for irrigation, public supplies and domestic purposes. Among 31 waters for which complete analyses were made, some 13 are mainly sodium chloride type waters, 7 are waters of sodium bicarbonate type and 11 are of mixed sodium chloride, sulphate and bicarbonate type. Sodium rather than calcium or magnesium appears to be the chief basic constituent of the waters, although data in this regard are not complete. Chloride is the main acid constituent in 16 of the waters, bicarbonate in 15 and sulphate in none. All of the waters samples are moderately to highly mineralized as is generally characteristic of groundwater in the arid and semi-arid regions of the world. Samples taken from some 416 shallow wells in the Bhuj series were analyzed for chlorides and used for the construction of Plates 4 and 8 which show areally the distribution of chlorides and general salinity in the shallow groundwater. These show that the salinity in the shallow groundwater of the Bhuj series is greatest in irrigated tracts and the least in undeveloped tracts. Deeper aquifers of the Bhuj series, as shown by samples taken from exploratory borings, generally contain water with higher salinity than that of shallower aquifers.

At the instance of the Kandla Port Authority, 8 deep exploratory borings were put down in the Anjar-Khedoi region as a part of the groundwater exploration and development programme for the Khandla Port Water Supply. The principal objectives of the exploratory programme were to determine the hydrostatic head, depth, thickness and lithologic character in the Bhuj series down to a maximum depth of 850 feet, to test the chemical quality of the water in the sandstone aquifers and to test the water-yielding capacity of sandstone aquifers at different depths by rough pumping tests. Both the conventional rotary and percussion methods were used in putting down the exploratory borings. Operations carried out included coring at 4 borings and collection of wash or bailer samples where cores were not available. Mechanical analyses were made of these samples in the Soils Laboratory of the Kandla Port Authority. Moreover, the samples were examined in detail by the writers and used in preparation of lithologic logs. Yield tests were made of 7 exploratory borings with from 2 to 5 tests of water-bearing zones at different levels in each boring. Observations during each test included measurements of discharge, static and pumping water levels and water sampling for chemical analysis.

Two controlled pumping tests were made of tube wells A_5 and B_3 in the Viri area during late October and early November 1951. Computations from these tests based on the Theis formula indicate that Upper Bhuj sandstone aquifers of the area have transmissibilities ranging from 64,000 to 157,000 U.S. gallons per day per foot. Coefficients of storage obtained from the pumping effect of tube well A_3 on other tube wells of the area ranged from 1×10^{-3} to 4×10^{-4} indicating confined conditions exist in the deeper Upper Bhuj aquifers of the area. The shallow groundwater is, however, under water-table or unconfined conditions. It is believed that the total pumpage from tube wells of the Viri area should not exceed 700,000 7 lakhs) Imperial gallons per day with an optimum draft averaging 500,000 (5 lakhs) gallons per day. A strong probability exists of contamination of the water of the tube wells by encroachment of brackish water from the southest side of the Viri inlier, if the indicated pumpage is exceeded for a prolonged period.

It is concluded that the average annual replenishment to Upper Bhuj aquifers of the Anjar-Khedoi region is just about in balance with present (May 1954) withdrawals for irrigation and public supplies and that there is no rejected natural recharge and very little salvageable natural discharge which can be recovered by diversion to pumped wells. Therefore development of new groundwater supplies from tube wells in the Anjar-Khedoi region would necessarily result in some curtailment of the supplies of existing irrigation wells. Surplus groundwater to the extent of about 2 million Imperial gallons a day could be developed from the Dudhai and Bhachau areas of eastern Kutch without excessive interference to the supplies of existing irrigation wells in those areas. Measures should be taken to utilize and develop existing and potential surface reservoirs on streams of the Gandhidham-Kandla Port hinterland so as to reduce the need for a continuous and heavy draft on the groundwater supply. Additional data regarding evaporation, local rainfall and monsoon run-off in the several stream systems of eastern Kutch are very much needed before surface water-resources can be properly evaluated.

INTRODUCTION

Location and extent of the area

The Anjar-Khedoi region as described in this report lies in Anjar *taluk* of eastern Kutch between latitudes 23°10′00″ and 23°00′00″ north and longitudes 69°52′30″ and 70°07′30″ east of Greenwich (Figure 1). Base maps used for the field work of the present investigation included Survey of India sheets Nos. 41E/16/5 and 41E/16/6 with scale 1:25,000 (·2534 inches to a mile) and the special Kandla Port sheets Nos. 1 and 3 with scale 1 : 15,840 (4 inches to a mile). In addition aerial photographs made by the Air Survey Co. of India on both the 4-inch and the 2½-inch scales were available for the present work. The map area extends some 16 miles from east to west and 11½ miles from north to south. It contains approximately 184 square miles. Anjar with a population of about 16,000 is the largest city in the region and Gandhidham (Adipur) township with a population approximately 6,000 is the second most important town.

Scope and purpose of investigation

The field investigation on which this report is based covered a 2-year period extending from June 1950 to June 1952 with continuing hydrologic observations through June 1954. The field work was carried out principally by Mr. B. D. Pathak, Assistant Geologist, Geological Survey of India. From February 1951 to May 1951 he was assisted by Mr. A. K. Saha, now Assistant Professor of Geology at Calcutta Presidency College. Mr. M. M. Oza, Assistant Geologist, Geological Survey of India worked with Mr. Pathak from November 1951 to January 1952 principally in the Khedoi and Khamra areas. Mr. R. N. Biswas, Surveyor, Geological Survey of India ran the instrumental levels to observation wells. Complete chemical analyses of water samples collected during February and March 1951 were made in the laboratory of the Geological Survey of India by Messrs. S. C. Chakravarty and M. K. De, Assistant Chemists. Mr. George C. Taylor, Jr., Groundwater Geologist of the U. S. Geological Survey, organized the field programme, participated for about 5 months in the field work and worked conjointly with Mr. Pathak in the compilation of the report.

The investigation was directed primarily toward determining the availability of groundwater supplies in the region for the Kandla Port project of the Government of India and the Gandhidham township of the Sindhu Resettlement Corporation. Secondarily attention was given to the availability of additional groundwater supplies for irrigation. Included in the investigation were (1) geologic mapping and delimitation of the principal aquifers of the region ; (2) preparation of a series of water-table maps to show the source, movement and discharge of the groundwater and seasonal changes in these features ; (3) a detailed inventory of existing wells and springs to determine the extent of present groundwater use for irrigation ; (4) observations of significant water-table fluctuations ; (5) preparation of an isochlor map to show the real distribution of salinity in the groundwater ; and (6) geologic and hydrologic observations at 8 deep exploratory borings in the Anjar-Khedoi region and at 4 tube wells in the Viri area—all put down by the Kandla Port authority. Owing to its importance as a source of groundwater supply for the beginning stages of the Kandla Port development, the Viri area was given particular attention in the field investigation. Groundwater conditions in this area are discussed in some detail in a following section of this report.

Acknowledgements

The present investigation was carried out under the general direction of Dr. J. B. Auden who was Superintending Geologist of the Engineering Geology and Groundwater Division, Geological Survey of India until December 1952. Dr. Auden's initial work (Auden, 1949, 26 pp.) on problems of the Kandla Port Water Supply was extremely helpful in planning the course of the present investigation. Later the investigation was completed and the report prepared under the direction of Dr. P. K. Ghosh who took over the Superintending Geologist's post from Dr. Auden. The writers are much indebted to Drs. Auden and Ghosh for inspiration and guidance.

To Mr. K. Mitter, Development Commissioner, Kandla Port, to Dr. Hans Gerdes, Chief Engineer, to Mr. M. Ramabrahman, Executive Engineer (Harbour), and to Mr. K. C. K. Moorthy,

Assistant Executive Engineer (Lands) the writers are grateful for many facilities which aided the progress of the work. Mechanical analyses of formation samples from the exploratory borings and the Viri tubewells were made in the Soils Laboratory of Kandla Port.

The writers also appreciate the help in various forms rendered by Mr. Pratap Dialdar, Managing Director, Sindhu Resettlement Corporation and other SRC officials in Gandhidham. Chemical analyses of water samples for the chloride maps and numerous analyses of water samples from the exploratory borings and from the Viri tubewells were made by Mr. M. J. Gulrajani, Chemist of the SRC Laboratory in Gandhidham and later, continuing analyses of samples from the Viri tubewells were made by Mr. A. H. Ahuje. Mr. M. K. Bhatti, Assistant Engineer, SRC, maintained the water-level recorder, pumpage records and other hydrologic observations of wells in the Viri area.

Mr. G. E. N. States, Drilling Supervisor, for the John Mowlems Co., Ltd., rendered very effective co-operation in carrying out tests required at the exploratory borings and in the Viri tubewells.

The writers also appreciate the valuable counsel and encouragement of Mr. H. M. Antani, Principal Irrigation Engineer, Government of Kutch who has worked for many years on the water problems of the State.

CLIMATE

The Anjar-Khedoi region like the rest of Kutch lies near the eastern limits of the great arid belt of southwest Asia. The climate of the region as classified by Koppen (Trewartha, p. 518) is that characteristic of the semi-arid low-latitude steppes of the world. According to this classification (1) there is a pronounced winter dry season, (2) there is at least 10 times as much rain in the wettest summer month as in the driest winter month, (3) the average annual temperature is greater than 64·4° F. No temperature or evaporation data are available for stations in the Anjar-Khedoi region. However, precipitation data as recorded by the Indian Meteorological Department for Anjar from 1878 through 1953 are given in Table 1 and are summarized in Table 2.

TABLE 1

Annual rainfall, in inches, at Anjar from 1878 to 1953

Year	Rainfall (inches)	Year	Rainfall (inches)	Year	Rainfall (inches)	Year	Rainfall (inches)
1878	26·98	1900	12·30	1922	11·54	1944	19·09
1879	8·49	1901	4·73	1923	4·17	1945	20·25
1880	15·63	1902	6·56	1924	7·66	1946	8·34
1881	22·76	1903	18·01	1925	9·44	1947	12·62
1882	21·27	1904	4·60	1926	27·24	1948	3·90
1883	21·45	1905	9·07	1927	19·54	1949	19·82
1884	23·74	1906	21·58	1928	11·32	1950	24·90
1885	8·20	1907	14·65	1929	13·43	1951	6·15
1886	19·59	1908	11·55	1930	11·41	1952	12·12
1887	11·49	1909	12·24	1931	4·57	1953	16·94
1888	11·76	1910	13·66	1932	14·48	..	..
1889	13·72	1911	2·16	1933	23·46	..	..
1890	10·02	1912	21·28	1934	9·78	..	..
1891	7·55	1913	29·77	1935	14·56	..	..
1892	11·78	1914	12·94	1936	11·25	..	..
1893	14·73	1915	9·46	1937	9·67	..	..
1894	37·34	1916	20·93	1938	7·37	..	..
1895	9·20	1917	22·88	1939	2·15	..	..
1896	22·42	1918	4·37	1940	8·50	..	..
1897	21·15	1919	10·37	1941	18·56	..	..
1898	12·25	1920	20·71	1942	8·10	..	..
1899	2·12	1921	20·57	1943	10·03	..	..

TABLE 2

Mean annual rainfall (inches)..13·95

Years of record..1878-1953

Total number of years of record..76

Maximum annual rainfall of record (inches) and year......37·34 (1894)

Minimum annual rainfall of record (inches) and year......2·12 (1899)

Average frequency of years with rainfall less than the mean...1:1·7

Average frequency of years with rainfall less than half the mean ....1:6·7

Average frequency of years with rainfall more than the mean...1:2·4

Average frequency of years with rainfall more than 1½ times the mean..1:12·3

TABLE 3

Average monthly rainfall in inches, at Anjar based on a 76-year average from 1878 to 1953

Month	Rainfall (inches)	Month	Rainfall (inches)
January	0·07	July	6·68
February	0·12	August	2·67
March	0·05	September	1·89
April	0·05	October	0·47
May	0·17	November	0·10
June	1·68	December	0·05
		Year	14·00

In 1950 a rain gauge was established at Gandhidham (Adipur). The monthly rainfall from 1950 through 1953 is given in Table 4 below:

TABLE 4

Rainfall, in inches, at Gandhidham (Adipur)

	1950	1951	1952	1953
January	0·00	0·00	0·00	0.00
February	0·00	0·00	0·00	0.00
March	0·00	0·00	0·00	0.00
April	0·00	0·00	0·00	0.00
May	0·00	0·00	0·00	0·00
June	0·03	1·71	0·29	0.62
July	24·77	4·78	9·90	4.26
August	0·26	3·11	1·95	10.11
September	4·03	0·28	0·23	3·16
October	0·00	0·00	0·07	0·00
November	0·00	0·14	0·00	0·00
December	0·00	0·00	0·00	0·00
Year	29·09	10·02	12.44	18·15

As indicated in Tables 3 and 4 about 90 per cent. or more of the annual precipitation falls during a 4-month period lasting from June through September. July is generally the wettest month in the year. The rainy season usually begins in late June with the advent of the southwest monsoon which brings moisture laden clouds from the Arabian Sea and continues in force until the first part of October. During the northeast monsoon which prevails from October to June light sporadic showers may occur occasionally but these are of relatively small importance for agriculture, for surface storage in tanks or for ground-water recharge.

As suggested by the summary of Table 2 the quantity of precipitation that falls in the Anjar-Khedoi region may vary greatly from year to year. Moreover, dry years may be expected with an average frequency of about one in 6·7 years. The areal distribution and intensity of rainfall during a given rainy season may be quite erratic in the Anjar-Khedoi region as well as in the rest of Kutch. For example in 1950 Gandhidham (Adipur) received 29·09 inches of rain but at Anjar which is only 4½ miles to the northwest the annual rainfall was 24·90 inches or 4·19 inches less.

In the 4-month period from November through February the weather in the Anjar-Khedoi region is generally agreeable with pleasantly warm days and cool nights. Daytime temperatures during this period seldom exceed 90° F. and night temperatures occasionally drop as low as 40° F. However, from March until the beginning of the rainy season the daytime heat is often oppressive and temperatures greater than 110° F. are common. Disagreeably hot winds with dust are also common in April, May and June. The heat is mitigated considerably by the southwest monsoon but when this wanes in October a brief hot spell generally occurs just before the beginning of cool winter weather.

PHYSIOGRAPHY

Stream erosion operating under semi-arid climatic conditions on moderately to gently folded sedimentary and volcanic flow rocks has resulted in most of the present land forms of the Anjar-Khedoi region which although small in area has considerable physiographic diversity. Important physiographic features of the region include (1) the Nigal upland which forms the eastern extension of the Chaduva Hills of central Kutch, (2) the Samparda ridge, (3) the Ratnal Hills, (4) the Mita Nadi upland, (5) the Khamra lowland, (6) the Midiada upland and Shinaya Hills, (7) the Viri lowland and (8) the Kidana lowland.

The Nigal upland lying in the northwest part of the map area (Plate 1) is coextensive with an elliptical structural dome which extends some 3½ miles from north to south and 4½ miles from east to west. Stream erosion has entirely removed the sediments forming the crest of the dome and encircling its broad structural apex has etched out a band some ½ to 2½ miles wide of low subparallel cuesta ridges separated by narrow discontinuous strike valleys in alternating hard and soft members of Lower Bhuj sandstones and shales. Within this band of valleys and ridges the local relief is generally about 50 to 75 feet and altitudes range from about 325 to 525 feet above sea level. The highest point in the Anjar-Khedoi region (548 feet above sea level) lies in this band about a mile south of the northwest corner of the map area. In the broad apex of the dome, erosion has breached through the relatively resistant sediments of the Lower Bhuj series and has carved out an almost level-floored basin (Sur Tallao) in soft shales of the underlying Katrol series. The basin floor lies at an elevation of 350 to 375 feet above sea level and extends some 2½ miles from east to west and 1½ miles from north to south. It is almost completely encircled (Plate 1) by the band of strike valleys and ridges in Lower Bhuj sediments which dip quaquaversally away from the crest of the dome.

In the north-central part of the region is Samparda ridge formed by a doubly plunging anticline whose axis trends east-southeast for some 3¾ miles (Plate 1). Along the crest of this fold erosion has etched out a chain of 6 miniature domes which are marked by almost circular quaquaversally dipping cuesta ridges with narrow intervening strike valleys in alternating hard and soft beds of Lower Bhuj sandstones and shales. Resistant beds of the same series also form alienated strike ridges around the basal flanks of the fold. The elevations on Samparda ridge generally range from about 325 to 400 feet above sea level with a high point (418 feet above sea level) about 1½ miles east-southeast of Samparda village.

Separated from the northwest end of Samparda ridge by a low gap about 3 furlongs wide is another doubly plunging anticline with an east-west axis forming the Ratnal Hills. These extend westward for about 4 miles to a point near the northwest corner of the map area. Here again erosion has etched out resistant Lower Bhuj sediments in quaquaversally dipping cuesta ridges around a chain of 4 miniature domes lying along the crest of the anticline and alineated strike ridges along the basal flanks of the fold. Only the southern slopes of the Ratnal Hills lie within the map area and generally range in elevation from about 400 to 485 feet above sea level.

Contiguous with Samparda ridge on the east is the Mita Nadi upland whose gently undulating surface rises gradually from an altitude of about 140 feet above sea level in the southeast to about 300 feet in the north-west with local relief generally less than 25 feet. The principal structural elements of this upland are (1) an open doubly plunging anticlinal fold whose axis trends east-southeast for about 6½ miles (Plate 1) and (2) an open subparallel syncline whose southwestern limb is faulted near the northeastern slope of Samparda ridge (Plate 1). Involved in these folds are the Deccan trap with its capping laterite and the overlying sediments of the Manchhar series. Over the crest of the anticline, erosion has stripped away Manchhar sediments and has partly removed the laterite. Low discontinuous homoclinal and cuesta ridges etched out by erosion in resistant trap flows, the " iron cap " of the laterite, and the basal conglomerate of the Manchhar are prominent on the north flank of the anticline and are also present but less conspicuous on the south.

Lying north, south and east of the Nigal upland, north of the Midiada upland and west of the Mita Nadi upland is the Khamra lowland which is approximately coextensive with the principal outcrop area of Upper Bhuj sediments (Plate 1). The Khamra lowland owes its topographic position and areal extent to the relatively uniform lithologic character and easy erodability of the soft Upper Bhuj sandstones. For the most part this lowland comprises almost level to gently undulating sandy plains broken by occasional low isolated sandstone buttes generally with a local relief of less than 30 feet. The lowland lies about 200 feet above sea level in the tract one mile southeast of Nagalpur and rises gradually westward to about 325 feet near Loharia and northwestward to about 400 feet in the area north of the Nigal upland. The Khamra lowland lies in a strike belt of Upper Bhuj sandstones to the south and southeast of the Nigal upland but its northwest salient lies in a narrow synclinal valley which passes between Samparda ridge and Ratnal Hills on the north and northeast and the Nigal upland on the south (Plate 1). Some 10 cultivated tracts irrigated from wells lie in the Khamra lowland.

The Midiada upland and Shinaya Hills are approximately coextensive with the principal outcrop area of the Deccan trap as shown on Plate 1. The northern margin of the Midiada upland and the southern limit of the Khamra lowland are marked by a conspicuous escarpment which generally trends westerly and west-southwesterly from Anjar passing near Sidungra and Khedoi to the western edge of the map area (Plate 1) through a distance of approximately 11 to 12 miles. The escarpment is of erosional origin and somewhat irregular in trend but generally faces northward with a local relief of about 50 to 75 feet. The elevations along the top of the escarpment range from about 320 feet above sea level near Anjar to 420 feet near the western edge of the map area. From the longitude of Viri westward to the western edge of the map area the flows of the Deccan trap dip uniformly southward at about one to 3 degrees and along bands of alternating hard and soft trap erosion has etched out well-defined cuesta ridges and strike valleys with a local relief of 50 to 75 feet. On the south, southeast and east the Midiada upland merges imperceptibly with the Kidana lowland at elevations of about 175 to 130 feet above sea level. The southeast salient of the upland is formed by the Shinaya Hills whose crest line lies about 175 to 250 feet above sea level. These hills are developed in an open southeastward plunging anticline (Plate 1) around whose nose pronounced cuesta ridges and strike valleys have been eroded out of alternate bands of hard and soft trap.

The Viri lowland is approximately coextensive with an inlier of soft Upper Bhuj sandstones that has been formed by the erosional breaching of a relatively thin cover of Deccan trap near the axis of the Shinaya anticline (Plate 1). This lowland is bound by low infacing scarps in trap with local relief of generally less than 50 feet. Elevations in the lowland itself range from about 200 to 225 feet above sea level. The Viri lowland contains the Viri irrigated tract, a rather large tract of phreatophytic vegetation and 5 production tube wells which at present (1954) furnish the principal water supply for Gandhidham township and Kandla Port.

Adjoining the Midiada upland on the east and south and the Mita Nadi upland on the northeast is the Kidana lowland which is approximately coextensive with the outcrop area of Manchhar sediments (Plate 1). The Kidana lowland comprises level plains which have local relief of less than 25 feet along streams. The lowland rises gradually from about 10 feet above sea level (high water line of ordinary spring tides) in the southeast corner of the map area to about 130 to 175 feet along the margins of the Mita Nadi and Midiada uplands.

The present drainage pattern of the Anjar-Khedoi region is probably inherited from a cycle of downcutting that began in Pliocene time in streams with courses consequent on gently folded surfaces in the Deccan trap and its overlying laterite cap. Over the Nigal upland, the Khamra lowland, the Samparda ridge and the Ratnal Hills, the trap and laterite cover was apparently thin and was quickly stripped away by streams which deposited their erosional debris in the Kidana lowland and contiguous lowlands to the north, northeast and east. At present the erosion cycle appears to be in the early mature stage of development. Relics of initial consequent drainage may be preserved in some segments of streams draining south across the southerly dip slope of the Midiada upland. Generally, however, competent streams such as Mathak, Midiada and Bhuvad Nalas have succeeded in capturing neighbouring drainage by means of extended subsequent tributaries which follow soft rock strike belts. In the Shinaya Hills subsequent drainage in soft rock belts is also well-developed (Plate 1). Over most of the area covered by the Nigal upland and the Khamra lowland initial consequent drainage has been to a large extent captured and diverted by subsequent tributaries of the Sang River. However, some of the original consequent drainage may still be preserved in the middle and upper reaches of Khedoi Nala.

DRAINAGE

With limited exceptions all of the streams of the Anjar-Khedoi region are of ephemeral character, that is, they carry water only in direct response to monsoon run-off but are dry during most of the year. The principal stream of the region is the Sang River which rises on the north slopes of the Chaduva Hills, enters the map area near the northwest corner, drains southeasterly and easterly by Nagalpur, Meghpur and Galpadar and finally empties into the tidal estuary of Nakti Creek about 4 miles northeast of the Kandla Port area. In the stretch extending about ¾ miles upstream from Viri reservoir the Sang carries a small perennial flows of about one cubic foot per second or less fed by ground-water discharge that is dissipated in the reservoir.

Elsewhere along its course the stream is ephemeral. The northeast part of the map area is drained by the Churwa River and its principal tributaries, the Mita Nadi and the Khara Sila. The Churwa empties into Nakti Creek about 7 miles north of the Kandla Port area. Shinaya Nala, which rises in several ramified tributaries in the Shinaya Hills, drains much of the southeast quarter of the map area and debouches into the tidal flats of Nakti Creek about 2 miles east of Barapur. Other important streams draining the southern and south-central part of the map area are Mathak, Midiada, Khedoi and Bhuvad Nalas which drain south to the Gulf of Kutch.

No reliable measurements are available for monsoon discharges in streams of the Anjar-Khedoi region. However, estimates of stream run-off and storage potentialities of reservoirs in the region based largely on the available rainfall records and the extent of catchment areas have been made in the report of the Kandla Port Water Supply Committee (1949) with accompanying appendices. Approximate estimates of run-off for the years 1933-40 based on the application of A. N. Khosla's formula to rainfall records are given in a report by Sardar Mansingh (Appendix 5, Report of Kandla Port Water Supply Committee, 1949) and are summarized below in Table 5.

TABLE 5

Year	Rainfall at Anjar (inches)	Approximate estimated run-off (acre feet)				REMARKS
		Sang at Viri	Mita *Nadi* near Warsamedi	Khedoi N. near Khedoi	Churwa R. near Satapur	
1933	23·46	11,670	1,550	7,070	5,370	Estimated run-off only during May, July and August.
1934	9·73	*Nil*	*Nil*	*Nil*	*Nil*	
1935	14·56	14,510	1,510	8,820	6,540	Estimated run-off only during July.
1936	11·25	*Nil*	*Nil*	*Nil*	*Nil*	
1937	9·67	*Nil*	*Nil*	*Nil*	*Nil*	
1938	7·37	*Nil*	*Nil*	*Nil*	*Nil*	
1939	2·15	*Nil*	*Nil*	*Nil*	*Nil*	
1940	8·50	*Nil*	*Nil*	*Nil*	*Nil*	

As based on Mansingh's calculations the general conclusions may be drawn that flood run-off in significant quantity does not generally occur in streams of the Anjar-Khedoi region except

(1) when the annual rainfall is about average (14·00 inches) or greater and (2) when the rainfall during the span of a month is about 5 inches or greater. The rains of deficient years such as those between 1936-40 are totally dissipated by evaporation, transpiration and infiltration to the ground-water body.

To conserve monsoon run-off dams have been constructed across and reservoirs formed on the Churwa River near Satapur, the Mita Nadi near Warsamedi, the Sang River near Viri, the tributaries of Shinaya *Nala* near Shinaya and the Sur *Tallao* near Nigal (Plate 1). The waters of Shinaya reservoir formed the principal supply of Gandhidham township and Kandla Port during 1950-51 but were not available during 1952-54. The storage potentialities and utilization of reservoirs in the Anjar-Khedoi region are discussed in some detail in reports by Sardar Mansingh (Appendix 5, Report of the Kandla Port Water Supply Committee, 1949) and M. B. Chablani (Appendix 6, Report of the Kandla Port Water Supply Committee, 1949).

GEOLOGY

Sequence and general features of the rocks

The rocks of the Anjar-Khedoi region include non-marine and marine sediments of Mesozoic, Tertiary and Quaternary age and the volcanic rocks of late Mesozoic to early Tertiary age. The oldest rocks exposed in the area are shales with minor sandstones of the Upper Jurassic Katrol series. These sediments are overlain by sediments of the Bhuj series (Rajnath, pp. 161-174, 1932) which comprise a lower unit of alternating non-marine sandstones and shales and an upper unit of massive current-bedded sandstones. The age of the Bhuj series may range from Upper Jurassic through Lower Cretaceous. The lava flows of the Deccan trap which is of Upper Cretaceous to Tertiary Eocene age directly overlie the Bhuj series but are absent in the north-western part of the map area probably owing to removal by erosion. Trap dykes and ferruginous-siliceous sandstone dykes in the Khamra lowland and the Nigal upland are also referred to the Deccan trap period. An extensive horizon of laterite developed at the top of the Deccan trap is placed in the post-Deccan trap Eocene. Mottled sandstone, fossiliferous sandstone, clay shale and conglomerate which overlie the laterite and the Deccan trap are referred to the late Tertiary Manchhar series and are probably Pliocene in age. Thin discontinuous bands of alluvium along the channels of the larger ephemeral streams of the region are considered to be of Quaternary age.

The sequence, lithology and water-bearing character of the several rock units of the Anjar-Khedoi region are summarized in Table 6 and are described in more detail on subsequent pages.

TABLE 6

Generalized stratigraphic section for the Anjar-Khedoi region

	Geologic age	Formation	Thickness (feet)	Lithology	Water-bearing properties
Quaternary	Pleistocene and Recent	Alluvium	Less than 20	Unconsolidated and with some gravel, silt and clay along channels of larger ophemeral streams.	Coarse facies yield small to moderate supplies of brakish water to wells.
Tertiary	Pliocene(?)	Manchhar series	0 to 615+	Semi-consolidated clayey sandstone and conglomeratic sandstone. Fossiliferous sandstones with siltstones and conglomerates. Clay shale. Lime-cemented conglomerate.	Yields meagre to small supplies of brackish Water to wells. Locally water is salty.
	Eocene (?)	Unconformity Laterite	0 to 30+	Ferruginous laterite (iron cap) and aluminous-ferruginous laterite derived *in situ* from Deccan trap flows.	Locally yields very meagre supplies of brackish to salty water to wells. Generally above the zone of saturation.
Cretaceous	Upper Cretaceous to Eocene.	Deccan trap	0 to 1,000+	Olivine basalt in alternating hard dense and soft amygdaloidal lava flows. Dykes of trap and ferruginous-siliceous sandstone.	Yields small to moderate supplies of good water to wells. Locally water is brackish.
	Lower Cretaceous	Unconformity Upper Bhuj series (stage)	0 to 1,000+	Medium to coarse, white to buff, current-bedded, friable sandstone with occasional partings of white silty shales.	Yields moderate to abundant supplies of good to brackish water to wells and springs.
Jurassic	Upper Jurassic to Lower Cretaceous	Lower Bhuj series (stage)	0 to 500+	Intercalated medium, current-bedded sandstone, micaceous silt-stone, variegated silty shales and buff, brown and grey flaggy sandstone.	Thicker sandstone members yield moderate supplies of good to brackish water to wells and springs.
	Upper Jurassic	Disconformity Katrol series	175+	Thin very hard brown sandstone at top underlain by grey and yellowish brown gypseous shales.	Will probably yield meagre supplies of brackish to salty water to wells.

Geologic history and stratigraphic relations of the rocks

The geologic history of the Anjar-Khedoi region begins with the deposition of the gypsiferous shales and hard sandstones of the Katrol series probably under estuarine conditions. No fossils have been found in the Anjar-Khedoi region in Katrol sediments but to the west of the map area in the Chaduva Hills the Katrol beds contain fossils referred to the Kimmeridgian and Portlandian stages of the Upper Jurassic (Rajnath, 1942, pp. 87-98).

A slight disconformity separates the Katrol series from overlying sediments of the Bhuj series and this according to Rajnath (1932, pp. 172-173) may represent an interval of post-Katrol erosion or non-deposition before the Bhuj was laid down. The Bhuj series as mapped in the Anjar-Khedoi region was separated on the basis of lithology into a lower unit of alternating sandstones, silty sandstones, shales and siltstones and an upper unit of soft, massive, current-bedded sandstones. The absence of marine fossils, the presence of poorly preserved plant remains and the physical character of the strata indicate deposition under alternating fluviatile and estuarine conditions in the lower unit and under predominantly fluviatile conditions in the upper unit. The Bhuj series or "stage" as originally defined by Rajnath (1932, p. 163) included the plant-bearing beds of the upper division of the Umia "series" of Waagen (1873, p. 1) and is approximately equivalent to the "Upper Jurassic series" of Wynne (1872, pp. 51-53). On the basis of stratigraphic relations with the marine Ukra beds of Aptian age in extreme western Kutch, Rajnath (1932, pp. 171-173) assigned a post-Aptian Cretaceous age to the Bhuj series. However, both the Ukra beds and the upper Umia *Trigonia* beds which have hitherto (Rajnath, 1932, pp. 170-171) been used to define the stratigraphic position of the plant-bearing Bhuj series, are evidently thin tongues of marine sediments which encroached but slightly into the western part of Kutch and are presumably absent in the central and eastern parts of the state. The writers are of the opinion that whereas the uppermost part of the Bhuj series may be of post-Aptian age there is strong probability that the rest of the series may range down through the Lower Cretaceous and into the Upper Jurassic. The Bhuj series as mapped in the Anjar-Khedoi region may thus be in part the terrestrial equivalent of the marine Ukra beds and perhaps in part equivalent with the so-called "barren rocks" (Rajnath, 1932, p. 100) which lie above the *Trigonia* beds and have been referred to the upper most Tithonian stage of the Upper Jurassic.

In most of Kutch the Bhuj series is separated from overlying lava flows of the Deccan trap by a slight unconformity which may represent a brief period of erosion or non-deposition. However, the attitudes of the Bhuj strata and of the overlying Deccan lava flows are in most places essentially parallel. In the Anjar-

Khedoi region the flows of the Deccan trap are generally absent in the Nigal upland and the Khamra lowland but in the southwest corner of the map area near Bhuvad the thickness of the flows may be as much as 1,000 feet. Elsewhere in southern Kutch the Deccan lava flows may attain a thickness of 2,500 feet (Wynne, 1872, p. 60). Associated with the extrusion of the Deccan lava flows in Kutch are numerous trap and ferruginous-siliceous sandstone dykes and dyke swarms. Good examples of each type of dyke occur in the northwestern quarter of the map area (Plate 1). The Deccan trap with associated dykes in western India has generally been assigned an age ranging from Upper Cretaceous to Lower Eocene (Krishnan, pp. 406-410).

Capping the Deccan trap in Kutch is a widespread zone of laterite whose age has been referred to post-Deccan Eocene because it is overlain by marine Eocene beds of the Laki series in western Kutch. This zone evidently corresponds to a prolonged period of subaerial weathering under a monsoon climate of alternating wet and dry seasons. In the Anjar-Khedoi region the laterite zone is well developed on the Deccan trap, particularly in the Mita Nadi upland.

In western and central Kutch the Deccan trap is generally overlain by a thick sequence of marine, estuarine and continental Tertiary strata of the Laki, Kirthar, Gaj, Nari and Manchhar series whose age ranges from Middle Eocene to Pleistocene (Krishnan, p. 446). However, in the Anjar-Khedoi region, the Laki, Kirthar, Gaj, Nari are absent and sediments referred to the Manchhar series of probable Pliocene age rest unconformably on the laterite and/or the Deccan trap. The lithologie character of Manchhar in the Anjar-Khedoi region suggests deposition under fluviatile, estuarine and shallow-water marine conditions.

Probably in conjunction with Middle Miocene (Krishnan, p. 414) and subsequent orogenic movements of the Himalayan region and of Sind and Baluchistan the rocks of Kutch were compressed into folds along three major anticlinal axes separated by broad synclinal depressions. The axes of the folds trend generally northwest-southeast in western Kutch but swing to an east-west trend in the central and eastern parts of the state. The great anticlinal structure of the Chaduva (Katrol) Hills in central Kutch extends eastward into the Anjar-Khedoi region as the Nigal dome and dies out in the smaller folds of the Ratnal Hills, Samparda ridge, the Mita Nadi upland and the Shinaya Hills, (Plate 1).

Physical character and water-bearing properties of the rocks

QUATERNARY SYSTEM

ALLUVIUM

Alluvium (map symbol, Qal) has only been separately mapped around Viri Reservoir on Sang River and near Paswalia Mita and Khara Paswalia along the Churwa River (Plate 1). Narrow bands of alluvium not shown in Plate 1 occur elsewhere in the region along the channels of Churwa River, the Mita Nadi, Sang River, Shinaya, Mathak, Midiada, Khedoi and Bhuvad Nalas. Through the Nigal upland and the Khamra lowland the alluvial bands along Sang River and Khedoi *Nala* are composed largely of medium to coarse unconsolidated quartz sand with fine quartz gravel and locally some silt and clay. The alluvial bands of streams crossing the Mita Nadi upland, the Midiada upland, the Shinaya Hills and the Kidana lowland contain sand and pebbles of ferruginous laterite and trap in addition to quartz sand and gravel. The thickness of the alluvial deposits along the channels of the larger streams is generally less than 20 feet.

The alluvial bands along the larger streams such as the Churwa River, Sang River and Khedoi Nala generally act as conduits for small but perennial underflow which is sustained by infiltration from flood run-off and by ground-water overflow from water-bearing beds in the Bhuj series, the Deccan trap and the Manchhar series. Shinaya Nala contains a rather substantial underflow sustained principally by leakage from Shinaya Reservoir. Small supplies of water for drinking, culinary and washing purposes are obtained from shallow wells dug in alluvium along stream channels particularly near Khambra, Meghpur, Satapur and Paswalia Mita. Typical is well 616 which is dug into a depth of 8½ feet in the sand and gravel of Khedoi Nala. This well lies about 1·4 miles northeast of Bhuvad and furnishes water of good quality for the use of travellers and livestock. Well 612 with a depth of 6 feet also taps underflow in sand and gravel of Khedoi Nala just east of Khambhra. This well is one of several dug in the stream channel that are used for domestic water supplies by the villagers. Along Sang River between Meghpur and Galpadar and along Churwa River near Satapur, Paswalia Mita, Khara Paswalia and Warsamedi, the water in the alluvium is of good to fair quality after monsoon run-off but becomes somewhat brackish with the progress of the dry season. The villagers of Satapur, for example, obtain water of fairly good quality from a few temporary wells less than 5 feet deep sunk in coarse unconsolidated sand in the channel of the Churwa. The supplies are reported to be adequate for domestic requirements.

TERTIARY SYSTEM

PLIOCENE (?)

Manchhar series

Physical character

The Kidana lowland in the eastern and southern parts of the map area is underlain by moderately consolidated fluviatile, estuarine and shallow-water marine clastic sediments referred the Manchhar series which have been subdivided into four mappable members in the Anjar-Khedoi region (Plate 1). These members with their corresponding map symbols in Plate 1 are (1) the mottled sandstone member (Tpcs), (2) the fossiliferous sandstone member (Tpms), (3) the clay shale member (Tpsh), and (4) the basal conglomerate (Tpcg). The clay shale and basal conglomerate members are notably lenticular and variable in thickness along the strike. Moreover, in many places along the margins of the Kidana lowland these members are absent owing to removal by erosion to non-deposition or to overlap by one or the other of the two youngest members of the Manchhar. Although the mottled sandstone member in its upper part is younger than the fossiliferous sandstone member it is possible that the two members may interfinger in the lower parts of their respective sections and may thus be in part contemporaneous. The fossiliferous sandstone member (Tpms) has not been recognized except in the southeast part of the map area (Plate 1). The general physical character of Manchhar sediments in the Anjar-Khedoi region is indicated by the sections of Tables 7 and 8.

TABLE 7

Section of the Manchhar series along the Churwa River about 1 to 3 furlongs east and southeast of Satapur.

	Feet
Mottled sandstone member (Tpcs):	
Sandstone, mottled yellowish to reddish-brown and pale gray, earthy to nodular structure, medium to coarse quartz grains in calcareous matrix, poorly bedded, moderately indurated Intercalated with beds 3 to 5 feet thick of (1) massive conglomeratic sandstone containing pebbles, ¼ to 4-inches diameter of quartz, hematite (?) laterite, ferruginous sandstone, chalcedony and trap in a quartz sand matrix with calcareous cement and (2) massive mottled reddish brown to pale gray, sandy clay shale	250+

TABLE 7—*contd.*

Clay shale member (Tpsh):	
Shale, clay, massive, soft, reddish-brown to pale gray with occasional scattered crystals and thin pods of gypsum. Occasional thin intercalated bands of fine siltstone and sandstone	165
Basal conglomerate member (Tpcg):	
Conglomerate, dark reddish brown, semi-consolidated, current-bedded, consisting principally of pebbles of hematite (?) laterite, weathered trap and occasional quartz and chalcedony ranging from 1/8 to 3-inches in diameter in a whitish calcareous clay matrix	200
Ferruginous laterite (iron-cap) at base	
Thickness of section	615+

TABLE 8

Section of the Manchhar series in *nala* just west of well 112 and 1¼ miles SSE of Antarjal

	Feet
Mottled sandstone member (Tpcs) at top,	
Fossiliferous sandstone member (Tpms):	
(A) Covered (mostly sandstone)	30
(B) Sandstone, fine to medium, silty pale gray to buff, compact, calcareous, with granules of quartz and some weathered trap and laterite and with poorly preserved fossils. Fine sandy siltstone parting at base	6
(C) Sandstone, medium to coarse, pale gray to buff, compact, calcareous, quartz grains with some hematite laterite pebbles, current-bedded, and scattered clay galls at base. Contains poorly preserved casts of lamellibranchs and gastropods near base	4
(D) Conglomerate, brownish yellow, compact, ½ to 2-inch pebbles of trap, hematite laterite, and hard clay in coarse quartz sand and matrix	2
(E) Sandstone, conglomeratic, yellow, compact, pebbles up to ½ inch diameter of quartz, hard clay, hematite laterite, and trap in a coarse sand matrix, current-bedded . .	3
(F) Conglomerate with subangular chert pebbles up to 6 inches in diameter in a poorly sorted sand matrix . . .	1

(G) Sandstone, compact, pale gray, current-bedded with runs of coarse to fine texture, conglomeratic near base with pebbles of hard clay, quartz, hematite laterite, and trap in a quartz sand matrix	3
(H) Sandstone, like (G) with thin partings of micaceous, current-bedded, brownish yellow siltstone near base	4
(I) Siltstone, white, micaceous, fine sandy, wavy banding	1
(J) Sandstone, like (G)	3
(K) Conglomerate, with pebbles of hematite laterite, trap and quartz, also large subangular cobbles of hard siliceous sandstone, hard clay and chert	1
(L) Sandstone like (G)	6
(M) Sandstone, fine to coarse, compact, highly lenticular bedding with runs of coarse conglomeratic sandstone and fine micaceous siltstone, pale gray to light brown	15
Basal conglomerate member (Tpcg):	
(N) Conglomerate, yellowish to reddish brown, semiconsolidated, current-bedded, with 1/8 to 2-inch pebbles of hematite laterite, trap and occasional quartz and chalcedony in a white sandy calcareous (kankary) matrix	35
Deccan trap (weathered) at base.	
Thickness of measured section	114

The mottled sandstone member is the youngest, thickest and most widely distributed of the 4 units comprising the Manchhar series in the Anjar-Khedoi region. Except in low bluffs along the Churwa and Sang Rivers the mottled sandstone member is only poorly exposed in shallow cuts along smaller ephemeral streams of the Kidana lowland. The best and thickest exposed section (250 feet+) is that along the Churwa River about one to 3 furlongs east and southeast of Satapur as described in Table 7. Discontinuous exposures 15 to 50 feet thick of similar sediments also occur along the Churwa River at Satapur, about 3 to 7 furlongs east-southeast of Khara Paswalia, and ¾ mile north of Warsamedi. In a quarry about 2 furlongs south-southeast of Warsamedi railway station the basal conglomerate the

the clay shale members are absent and the mottled sandstone member rests directly on laterite. Exposed in the quarry faces are some 15 feet of moderately indurated fine-grained, current-bedded gray, quartzose sandstone intercalated with coarse conglomeratic sandstone containing pebbles of weathered yellowish brown trap and reddish brown laterite in a pale gray coarse sandy matrix. Small exposures of sediments of very similar lithology to those described in Table 7 occur discontinuously along Hadkiya River in the stretch between the Sang River confluence and the Anjar-Bhachau highway and also along Sacha Boli Nalȧ about one mile southeast of Anjar. Along Sang River the mottled sandstone member is exposed in small cuts 5 to 20 feet high at points one furlong east of Meghpur, at the railway bridge 7 furlongs east-northeast of Meghpur and about 1¼ miles west northwest of Galpadar. Again at these points the sediments exposed are very much like those described in Table 7. The mottled sandstone member assumes a somewhat different lithologic character in low bluffs along Shinaya Nala near Kidana. Just southwest of the village 10-foot cuts in nala banks show pale yellowish grey, hard, current-bedded sandstone in lenses 2 to 3 feet thick intercalated with thin stringers of clay shale one to 6 inches thick and crudely bedded mottled reddish brown to gray silty sandstone containing occasional pods of pure hard dense limestone. About ¼ mile south of Kidana along Shinaya Nala this section is overlain by about 10 feet of interbedded fine sandy siltstone and well bedded pale yellow to white, non-calcareous shale and mottled nodular calcareous sandstone. On the east bank of Khedoi Nala at Khambhra the mottled sandstone member is fairly well exposed in 10 to 15-foot cuts which show medium to coarse, mottled reddish brown and gray, crudely bedded, conglomeratic sandstone with pebbles of hematite laterite, trap, quartz and chert in a fine clayey silty calcareous matrix. The section here also markedly resembles that of Satapur (Table 7.)

The fossiliferous sandstone member crops out only in the south-eastern part of the map area (Plate 1) where it may be partly intercalated with the mottled sandstone member. The thickest section (79 feet) of the fossiliferous sandstone member exposed in the region is that described in Table 8. Outcrops of sandstones of similar lithology occur in cuts along Shinaya Nals about one-half mile west of Antarjal and along the anticlinal fold lying about 2 to 2½ miles south and southwest of Shinaya (Plate 1). In shallow quarries about 1¼ miles east of Mathak hard, pale yellowish gray, medium-grained sandstone is well exposed. The sandstone here contains abundant fossils most of which are poorly preserved. Palaeontologic examination (Jacob *et al*, p. 68) indicates the presence of Chara "fruits", Ostracoda, the miliolid genus *Quinqueloculina* and a few small gastropods. Although not conclusive the fossil assemblage suggests a late Tertiary to Pleistocene age for the sandstone.

The clay shale member attains its greatest thickness and is most extensively exposed in the strike belt lying on the north flank of the Warsamedi anticline (Plate 1). The member is absent or not exposed around the eastern nose of the Warsamedi anticline but reappears in a tract lying about 1½ to 2 miles northeast of Anjar. Elsewhere along the inner margin of the Kidana lowland the clay shale member is absent except for a narrow band lying about 5 furlongs north of Khambhra (Plate 1). Here the member is only 10 feet thick but on the north flank of the Warsamedi anticline it may attain a thickness of as much as 200 feet. In most observed outcrops the lithology of the clay shale member resembles that of the Satapur section described in Table 7.

The most extensive exposures of the basal conglomerate member occur in the Mita Nadi upland and in a strike belt lying on the north flank of the Warsamedi anticline (Plate 1). Smaller exposures appear about one-half mile west-northwest of Meghpur and about 1¼ miles east to southeast of Shinaya. Another extensive belt of the basal conglomerate extends in a general east-west direction from a point about 1½ miles northwest of Mathak to about 2½ miles west of Khambhra. The thickness of the basal conglomerate varies greatly along the strike. Thus 5 furlongs north of Khambhra it is 20 feet thick, in the measured section of Table 8 it is 35 feet thick and near Satapur (Table 7) it reaches a maximum thickness of 200 feet. In intervening stretches along the margin of the Kidana lowland the basal conglomerate is absent owing to removal by erosion, to non-deposition or to overlap by younger members of the Manchhar series. The lithology of the basal conglomerate is in most outcrops quite similar to that described in the sections of Tables 7 and 8.

The Manchhar sediments were involved in the late Tertiary folding movements which affected the Anjar-Khedoi region so that in most exposures along the margins of the Kidana lowland and in the Mita Nadi upland gentle to moderate dips are observed in the strata. On the north flank of Warsamedi anticline the dips in Manchhar sediments range from 15 to 35 degrees in a northerly direction and on the opposite flank are southerly at

257391

about 2 to 6 degrees. Near Meghpur and Anjar the dips in Manchhar sediments are easterly and northeasterly at 2 to 35 degrees. Around the nose of Shinaya anticline the dips range from 2 to 15 degrees and swing northeasterly through easterly to a southerly direction. The sediments near Galpadar are essentially horizontal. The thickness of sediments in the Manchhar series ranges from a feather edge to an observed maximum of 615 feet near Satapur (Table 7) but a greater thickness may occur along the eastern margin of the map area. Based on paleontologic examination of fossils from the fossiliferous sandstone member in the quarries 1¼ miles east of Mathak, the Manchhar series is tentatively assigned a Tertiary Pliocene age in the Anjar-Khedoi region.

Water-bearing properties

Among the 4 units of the Manchhar series there is considerable variation in capacity to absorb water at the land surface and to transmit water in the zone of saturation. However, none of these units contains markedly productive water-bearing layers. The basal conglomerate member generally has a moderately indurated fine-grained sandy to clayey matrix and is not likely to yield more than very limited supplies of water to wells. The clay shale member is even more tight and impervious than the basal conglomerate and is probably the least productive of the Manchhar series.

The fossiliferous sandstone member has perhaps slightly more capacity to store and transmit water than any of the other members of the Manchhar series. Although much of the original permeability of component sandstone and conglomerate strata has been reduced by secondary cementation, there are occasional thin pervious layers of soft friable sandstone or conglomeratic sandstone that store and transmit considerable water. In addition some water is also contained in bedding planes, joints and other partings in the rock. Water-bearing layers in the fossiliferous sandstone member supply some 70 shallow dug wells which are concentrated in a tract about ¾ to one mile south of Kidana, in a strip about 1½ miles long lying ½ mile south to 1½ miles west of Kidana, in a strip extending from Barapur for 1¼ miles northwest and a tract lying 1½ to 2 miles south-southeast of Shinaya on the Tuna road. All of these tracts lie in the southeastern part of the map area (Plate 1). During the course of field work 18 representative wells in these tracts were examined. Hydrologic data for each well visited are given in Appendix 15 and the well locations are shown in Plate 1. The wells examined range from 17 to 54 feet deep with water levels

10 to 37 feet below land surface. Among the 18 wells the sustained capacities per individual well range from 5,000 to 15,000 gallons per day, used largely for intermittent or seasonal irrigation of 2 to 5-acre plots of wheat and millet. The water is generally slightly to moderately brackish.

Water in strata of the mottled sandstone member is transmitted and stored largely in thin pervious sandstone or conglomerate layers intercalated with somewhat indurated sandstones and conglomerates whose initial permeability has been considerably reduced by secondary cementation. Relatively few wells develop water from the mottled sandstone member owing to the prevailing poor quality which is generally inferior to that of water in the fossiliferous sandstone member. Wells 30, 31 and 32 in Gandhidham (Adipur) are 111, 116 and 110 feet deep, respectively and all tap water which is presumed to be in pervious sandstone or conglomeratic sandstone layers intercalated in the mottled sandstone member. The depth to water in these wells ranges from about 45 to 65 feet below land surface. Among the 3 wells the sustained capacities range from about 7,000 to 20,000 gallons per day. The water is markedly brackish and finds only limited use. About ½ to one mile west and southwest of Galpadar are several small 2 to 3-acre plots irrigated by wells tapping water-bearing layers in the mottled sandstone member. The water is only slightly brackish. Typical are wells 550, 551 and 552 which are 37, 138 and 51 feet deep, respectively. Well 551 was first dug to 58 feet and then deepened by boring to a total depth of 138 feet. This well has a sustained capacity of about 20,000 gallons per day but other shallower wells in the same tract probably do not yield more than about 10,000 to 12,000 gallons a day each.

In most places the water in Manchhar sediments in slightly to markedly brackish. Locally, however, the water in the fossiliferous sandstone member in the irrigated tract such as near Barapur and Kidana is used for intermittent irrigation of salt resistant millet-apparently without harmful effects. Likewise the water in the mottled sandstone member near Galpadar is also used for irrigation of millet. To the east of Gandhidham, Antarjal and Kidana there is a gradual increase in salinity as the tide limit is approached. Analyses of typical waters from Manchhar sediments are given in Appendix 2 for well 31 near Gandhidham and for well 45 in Sardarganj which is just east of the map area (Plate 1). Other analyses for well 600 which is 1½ miles east of Shinaya and well 605 which is 7 furlongs south of Kidana are given in Appendix 4. These are typical of waters in the fossiliferous sandstone member of the Kidana-Barapur area.

EOCENE (?)

LATERITE

In kutch an extensive horizon of laerite is commonly developed at the top of the Deccan trap and corresponds to a prolonged period of weathering and deep *in situ* decay of the host rock under a monsoon climate of alternating wet and dry seasons. Nummulitic limestones of the Eocene Laki and Kirthar series overlie the laterite horizon in western Kutch but. in the central and eastern parts of the state the laterite is covered by progressively younger Tertiary formations. Thus in the Anjar-Khedoi region sediments of the Manchhar series rest directly on the laterite. Owing to the stratigraphic relations in western Kutch the age of the laterite horizon is generally referred to the Eocene.

The laterite horizon in the Anjar-Khedoi region is most extensively exposed in the Mita Nadi upland, particularly on the flanks of the Warsamedi anticline (Plate 1). Around the margins of the Midiada upland and the Shinaya Hills the laterite horizon is not generally well exposed either because of removal by erosion or because of overlap by Manchhar sediments. However narrow bands of laterite crop out about 1¼ miles southeast of Shinaya and again in the crest of a sharp anticlinal flexure about 1⅞ miles south-southeast of the village (Plate 1). For purposes of mapping in Plate 1 the laterite horizon has been divided into an upper unit of ferruginous laterite or " iron cap " (map symbol, Teic) and a lower unit of aluminous-ferruginous laterite (map symbol, Tel). However, both of these units are essentially gradational into one another. Along the north flank of Warsamedi anticline the laterite horizon crops out discontinuously for more than 4½ miles although in this stretch the best exposures occur on the south slope of hill " 232 " about ½ mile south of Paswalia Mita. Here a typical section from top to bottom is described below in Table 9:

TABLE 9

Top of section at summit of hill " 232 "

	Feet
Ferruginous laterite (iron cap):	
(A) Laterite, hematitic, dark red to reddish brown to purple compact, dense to spongy texture, very rich in iron oxides grading downward into unit (B)	15

Aluminous and ferruginous laterite:	
(B) Laterite, aluminous clays, soft, unctuous, white to mottled yellowish and yellowish brown grading downward into unit (C)	10
(C) Laterite, ocherous and aluminous, soft mottled yellow to yellowish brown earthy limonitic ochre mixed with white aluminous clay grading downward into weathered trap .	5
Deccan trap (weathered) at base:	
Thickness of section . .	30

The "iron cap" unit is moderately resistant to erosion and forms conspicuous cuesta ridges which serve as convenient stratigraphic markers around the folds of the Mita Nadi upland (Plate 1). On the other hand, the aluminous-ferruginous unit is quite soft and generally does not crop out distinctly except where protected by the "iron cap".

Other good outcrops of the laterite section are exposed in hill "198" located about 1⅜ miles south of Paswalia Mita on the south flank of the Warsamedi anticline. Here the "iron cap" is about 5 feet thick and consists of compact mottled dark red, reddish brown to purple iron-rich, spongy hematitic laterite. This rests on about 15 feet of mottled white, yellowish brown and reddish brown ocherous and aluminous clays which grade downward into unweathered trap.

About ⅜ mile north-northwest of the Anjar ginning factory and ¼ mile south-southeast of well S13, outcrops along a small *nala* shows banded laterite consisting of alternating streaks 2 to 3 inches wide of soft, white aluminous clay and yellowish, yellowish brown and dark reddish brown limonitic to hematitic clay. This material rests on a white speckled bluish weathered trap containing lumps and nodules of dark reddish brown hematite. Similar exposures of banded laterite occur in shallow cuts just north of the Anjar-Bhachau highway at 1⅝ miles and 2 miles by road west-southwest of Warsamedi.

Aluminous laterite is well exposed in a knoll about 30 feet high lying 1¼ miles southwest of Satapur. The material here is mottled pale yellow to pale gray and of fine earthy texture. The alumina content is apparently quite high and the area may be worthy of additional prospecting for bauxite ores.

Although no systematic sampling of the laterite was carried out during the present ground-water investigation, it is believed that the laterite horizon in the Anjar-Khedoi region as well as in other parts of Kutch may hold considerable promise as a potential source of iron (hematite) and aluminium (bauxite) ores and useful clays. Detailed mapping, sampling and considerable test drilling of the laterite horizon would be required to determine the extent and grade of the deposits. The "iron cap" unit would presumably contain potential iron ores and the aluminous-ferruginous unit some bauxite ores, locally of economic grade as well as useful red and yellow ochre and clays. However, samples collected from the aluminous-ferruginous unit of 3 different localities in the Anjar-Khedoi region were analysed in the Geological Survey of India laboratory by S. N. Gupta. These analyses indicate composition essentially equivalent to lithomarge with a high silica content in samples 1 and 3 and a high iron content in sample 2. As such the materials would not be particularly satisfactory as aluminium ores. The analyses are given below in Table 9A.

TABLE 9A

Constituents	(Percent)		
	Sample 1	Sample 2	Sample 3
SiO_2	32·76	18·76	35·44
Al_2O_3	36·12	26·20	42·78
Fe_2O_3	3·64	21·46	3·24
MgO	Trace	Trace	Trace
CaO	4·03	7·56	Trace
TiO_2	Trace	Trace	Trace
Loss on ignition	23·60	26·32	18·70
TOTAL . .	100·15	100·30	100·16

Sample No. 1. Collected from the slope of a laterite nubbin about 3 miles N W of Anjar along cart track from Anjar to Khara Paswalia.

Sample No. 2. Collected from a point one-half mile N W of milepost 3 on the Anjar-Bhachau highway.

Sample No. 3. Collected from a point about one-half mile S W of Khara Paswalia on left bank of Churwa River at crossing of cart track to Anjar.

The laterite horizon like its host, the Deccan trap, and the overlying Manchhar series was involved in late Tertiary folding Thus in most exposures the laterite shows gentle to moderate dips. On the north flank of the Warsamedi anticline the dips in the "iron cap" are northerly at from about 2 to 18 degrees and on the south flank they are southerly at 2 to 10 degrees. Elsewhere in the Mita Nadi upland dips of less than 5 degrees prevail in the laterite horizon. Over much of the Anjar-Khedoi region the laterite cover on the Deccan trap has been entirely stripped away by erosion. The greatest thickness of laterite occurs in the Mita Nadi upland in which a maximum of about 35 feet is exposed on the north flank of the Warsamedi anticline.

The "iron cap" unit is generally too thin and discontinuous to be important as a water-bearing formation. Moreover, it generally lies above the water table in the Anjar-Khedoi region. The aluminous-ferruginous unit is equally thin and is not generally water-bearing, except perhaps locally.

CRETACEOUS AND TERTIARY SYSTEMS

DECCAN TRAP

Lava flows

Physical character

Lava flows of the Deccan trap crop out or lie near the land surface in all of the Midiada upland and the Shinaya Hills and in much of the Mita Nadi upland. The trap flows are absent in the Kharma lowland, the Nigal upland and the Ratnal and Samparda Hills, probably owing to removal by erosion. In the Kidana lowland the trap flows are concealed beneath a considerable thickness of Manchhar sediments. The individual flows of the trap sequence range from very hard, dark gray to black, dense, non-vesicular olivine basalt to soft, earthy brown to gray amygdaloidal basalt. Lava flows predominate in the sequence although thin discontinuous beds of tuff and fresh-water limestone are locally intercalated. A typical section of the trap examined by Mr. B. D. Pathak is described in Table 10 below:

TABLE 10

Section of the Deccan trap from a point 1½ furlongs south of Devalia northward for 3½ miles along longitude 70°00′E. to the south edge of the Viri lowland.

	Feet
Top of section at contact of basal conglomerate member of Manchhar series, 1½ furlongs. south of Devalia.	
(A) Basalt, soft, earthy, dark brown to gray, amygdular, zeolitiferous with reticulated veinlets of calcite Forms lowland	150
(B) Basalt, hard, dense, fine-grained non-vesicular flow greenish black	30
(C) Basalt, like (A)	40
(D) Basalt, hard, vesicular flow with some amygdules of agate	60
(E) Basalt, hard, dense, non-vesicular flow	25
(F) Basalt, soft, earthy black to brown with amygdules of agate, calcite and zeolites. Forms lowland	175
(G) Basalt, amygdaloidal flow with amygdales of agate, calcite and green zeolites	50
(H) Basalt, sheeted and fractured, also columnar jointing with partings filled with calcite and earthy calcium carbonate. Black near top ranging down to brown and gray near base	125
(I) Basalt, dense, hard, black, jointed, non-vesicular. Form low strike ridge	50
Base of section at contact of Upper Bhuj series at south edge of Viri lowland. Approximate thickness of section	705

The thickness of the individual lava flows generally ranges from about 20 to 50 feet in the Anjar-Khedoi region. However, it is generally difficult to distinguish the tops and bottoms of individual flows owing to the low relief of the trap country and to the poor exposures. Thus in Table 10 units A, F and H probably contain 2 or more lava flows each so that as many as 13 or more flows may be represented in the described section. From the south-western corner of the map area north to the escarpment at the edge of the Khamra lowland there may be as many as 20 lava flows present in the Deccan trap sequence.

The individual flow units described in the section of Table 10 can generally be traced for considerable distance along the strike even though precise flow contacts cannot always be distinguished. Thus, the soft trap of unit (A) in Table 10 forms a strike belt that can be followed westward from Devalia to Bhuvad and thence to the west edge of the map area. Likewise the same belt extends eastward from Devalia, passes along the south slope of the Shinaya Hills through wells 142, 143, 135 and 137, swings north around the nose of the Shinaya anticline (Plate 1) through well 139 and continues north and northwest along the flank of this structure, at least to the latitude of strike belt trending subparallel to that of unit (A). Thus Meghpur. The soft trap of unit (F) in Table 10 also forms a Shinaya reservoir lies in an arcuate lowland carved by erosion out of the soft trap of unit (F) on the plunging nose of Shinaya anticline. The low ridge of hills along the southern and eastern rims of the reservoir are formed by more resistant basalt flows which are the strike extensions of (D) and (E) of Table 10. Petrographic examination was made of a sample from flow unit (D) taken from a point one-half mile north of Devalia. The rock is hard dark greenish gray somewhat vesicular basalt with a finely sub-ophitic intergrowth of plagioclase (labradorite?) lathes and pyroxene (augite?) with some palagonite making up the ground mass and with phenocrysts of augite and feldspar. The rock also contains olivine and relatively abundant iron ores which are principally magnetite. Flow unit (I) of Table 10 forms a well-marked strike ridge along the south side of the Viri lowland that can be followed westward for about 2 miles to the longitude of Midiada and eastward to the crest of the Shinaya anticline (Plate 1). Petrographic examination was made of a rock sample from flow unit (I) taken about one mile southwest of Viri and just south of well 49 (Plate 1). The rock is a compact dense fine-grained non-vesicular basalt whose groundmass is a finely ophitic intergrowth of plagioclase lathes and augite with small augite phenocrysts. The rock also contains chlorite (?), olivine and iron ores. Another rock sample for petrographic examination was taken from a point on the Viri-Gandhidham pipe line about one mile southeast of the southeast abutment of Sang Dam. The rock is a purplish gray compact amygdaloidal basalt with amygdules of crystalline calcite, cryptocrystalline silica and zeolites. It apparently corresponds in stratigraphic position to flow unit (G) of Table 10. In thin section the rock is a very finely ophitic intergrowth of altered plagioclase lathes and pyroxene with tiny amygdules containing calcite and cryptocrystalline silica.

The best exposures of the trap flows occur along the Sang River near the existing Sang Dam (at Viri reservoir) and near the proposed Viri Dam about ½ mile north-northeast of Viri. Just downstream from the proposed dam are bluffs some 50 feet high along the Sang that expose massive fine grained, non-vesicular basalt with well-developed polygonal jointing. Petrographic examination was made of a rock sample taken from the bluffs about 5 furlongs north of Viri (Pathak, June 1951, Appendix I). The chief mineral constituents in the groundmass are granular augite, lathes of feldspar (plagioclase?), iron ore and some greenish brown palagonite with tiny phenocrysts of feldspar. Additional petrographic descriptions of rock samples from trap flows lying stratigraphically below flow unit (I) of Table 10 are given in a report (Pathak, June 1951, Appendix I) on concrete aggregate sites for the Kandla Port project near Viri and Anjar.

Intercalated with the trap flows are thin beds of basaltic tuff and agglomerate. However, these beds occur only locally and are not generally important in the trap sequence. About 6½ furlongs south-southeast of Viri and one furlong southwest of well 25 P is an intertrappean bed of limestone about 3 feet thick which crops out along a strike distance of about 600 yards. The rock is fine-grained, white, compact limestone with narrow veinlets of calcite. Similar intertrappean limestone although somewhat cherty caps a low butte about 5 furlongs east-southeast of well 25 P (Plate 1). The limestone bed occurs in the lower part or at the base of horizon (H) as described in Table 10 and is possibly of fresh-water or lacustrine origin. Limestone of pale gray colour and fine-grained texture has also been observed filling joints and fractures in basalts of flow unit (H) (Table 10) about one furlong east of well 610 (Plate 1).

Like overlying Tertiary sediments and underlying Mesozoic strata, the lava flows of the Deccan trap were involved in late Tertiary folding movements in the Anjar-Khedoi region as well as in other parts of Kutch. Thus in the Mita Nadi upland the trap flows show northerly dips of 6 to 19 degrees on the north flank of Warsamedi anticline and southerly dips of 4 to 11 degrees on the south flank. Around the flanks of Shinaya anticline dips are generally from 2 to 5 degrees. The trap flows in the Midiada upland have fairly uniform southerly dips ranging from one to 3 degrees.

The Deccan trap sequence has a considerable range of thickness in the Anjar-Khedoi region. Thus along the northern margin of the Midiada upland the trap thins out to a feather edge or is breached by erosion to form numerous inliers in the underlying Upper Bhuj series near Viri, Anjar and Mathada. (Plate 1). However, the trap sequence thickness rapidly southward and southeastward. Thus judging by the exposed section described in Table 10, the trap sequence may be about 700 feet thick near Devalia. In the southwest corner of the map area the accumulated thickness of trap flows is estimated to be of the order of 1,000 feet and a similar thickness may also be present in the southeast corner of the map area beneath a thick cover of Manchhar sediments.

Water-bearing properties

Water in the lava flows of the Deccan trap is stored and circulated principally (1) in joints, fracture and other secondary partings in the more brittle flows and (2) in soft earthy trap rendered pervious by weathering. Intertrappean beds are of limited extent in the Anjar-Khedoi region and hence are relatively unimportant as aquifers. Moderately to highly pervious cavernous, scoriaceous and fragmental zones at the tops and bottoms of successive lava flows that are common in the plateau basalts of northwestern U.S.A. and that form important conduits for deep percolation of ground water are absent or poorly developed in the lava flows of the Deccan trap of western India. Thus there is very little or no facility for deep percolation of ground water in the trap flows of the Anjar-Khedoi region. The conclusion is borne out by the results of many deep borings put down in trap to depths of as much as 1,000 feet or more in the neighbouring state of Saurashtra. There the trap flows have been shown to contain very little or no water below depths of 150 to 200 feet.

Throughout most of the Midiada upland and the Shinaya Hills small to moderate supplies of water for small-scale irrigation, domestic and stock use are obtained from trap flows within depths of less than 75 feet below land surface. Wells located on trap hills and hill slopes are generally somewhat less productive than those in the valleys or low ground where the trap is generally more pervious and where ephemeral streams supply local recharge. The water in the trap is generally of fair chemical quality and generally better than that in Manchhar sediments. Locally, however, the water is brackish. The absence of ground-water development in the trap flows of the Mita Nadi upland may be due to poor quality of water. The water analyses of well 138 near Shinaya and wells 24 P, 27 P, 32 P and 69 in the Viri area are typical of the quality of water in the trap. The analyses are given in Appendix 4.

Water from trap has been developed by shallow wells for small-scale irrigation near Bhuvad, Shinaya. Viri and Anjar but elsewhere in the region only scattered domestic and stock wells have been dug in the trap. Within ¾ mile to the south and west of Bhuvad are some 15 shallow wells which develop water from trap for small-scale irrigation. Wells 465, 614 and 615 are typical of this area (Appendix 15). All 3 wells develop water from soft disintegrated trap corresponding the flow unit (A) of Table 10. The wells range from 33 to 43 feet deep with water levels from 29 to 40 feet below land surface. The sustained capacities of the wells range from approximately 7,000 to 12,000 gallons per day per well and are used for intermittent irrigation of 1 to 3 acre plots.

Some 25 shallow wells used for intermittent small-scale irrigation of one to 3 acre plots tap water in trap in the area lying from ½ mile south to one mile southwest and west of Shinaya. Typical are wells 135, 137, 138 and 140-143 all of which obtain water from soft amygdaloidal trap corresponding to flow unit (A) of Table 10. The total depths of the wells range from 22 to 46 feet with water levels from 16 to 27 feet below land surface (Appendix 15). Individual wells in this group may yield from about 7,000 to 10,000 gallons per day on a sustained basis.

In a belt extending from Viri for about one mile north of the village there are some 11 shallow wells which draw water from pervious fractured and jointed trap at depths of from 22 to 54 feet. The water levels in the wells range from 11 to 37 feet below land surface. The wells have sustained capacities of about 4,000 to 16,000 gallons a day and average about 10,000 gallons a day. All are used for irrigation of small plots of grains, fruits and vegetables.

Within a distance of ¾ mile to the north, west and southeast of Anjar are some 10 wells which end in jointed and fractured trap at depths of 29 to 52 feet and whose water levels lie from 17 to 46 feet below land surface. Most of these wells are used for domestic and public purposes. However, well 27 yields about 14,000 gallons a day for small-scale irrigation.

Dykes and sills

Several conspicuous trap dykes and ferruginous-siliceous sandstone dykes which cross-cut Bhuj and Katrol sediments in the Khamra lowland and the Nigal upland are referred to the Deccan trap period. From a point near Sang River 6 furlongs south-southeast of Mota Nagalpur extending westerly for 5 miles through Sidungra to a point about 3 furlongs southeast of Pantia is the Sidungra trap dyke which intrudes sandstones of the Upper Bhuj series (Plate 1). A northerly offset of about 300 feet occurs in the dyke line at a point about 5½ furlongs west of Sidungra. Throughout its length the dip of the dyke on the outcrop is vertical. The width of the dyke one furlong west of the east end is 30 feet; ½ mile east of Sidungra it is 15 feet; 3½ furlongs west of Sidungra it is 40 feet and 1½ furlongs west-southwest of well 158 it is 63 feet. Along the strike length the dyke rock is generally a dense hard non-porphyritic dark gray to black fine-grained basalt. Examination of thin sections of rock samples taken from points 7 furlongs southwest of Khamra and 3½ furlongs west of Sidungra indicate that the dyke rock is an ophitic intergrowth of lathe shaped plagioclase (labradorite?) crystals and pyroxene (augite?). Some olivine, chlorite and iron ores are also present.

The Pantia trap dyke which is separated from the west end of Sidungra dyke by a gap of 2¼ furlongs begins about 2 furlongs south of Pantia (Plate 1) and extends west-southwesterly for 5 furlongs. About 3 furlongs southwest of Pantia the dyke is well exposed in the bed of small ephemeral stream. Here the dyke is 38 feet wide and has a strike of N. 80° E. with a dip of 73° north. The rock is hard, black, non-porphyritic, fine-grained basalt which cross-cuts coarse reddish brown Upper Bhuj sandstones.

The Loharia trap dyke continues the same west-southwesterly trend of the Pantia dyke but is separated from it by a gap of about 5 furlongs (Plate 1). The Loharia dyke is about 5 furlongs long and to the south about 100 yards it is paralleled by a narrow trap dyke about 2 furlongs long. At well 418 about one furlong southeast of the village, the Loharia dyke is about one foot wide. The strike is N. 85° E. and the dip, 60° north. The dyke rock is a very fine-grained to almost glassy basalt which is composed of clusters of plagioclase lathes in a cryptocrystalline ground mass with some iron ores and palagonite (?). The shorter dyke to the south also averages only about one foot wide with a strike of N. 80° E. and a dip 75° north. The dyke rock is a dark reddish brown finely fractured and altered basalt composed of altered feldspar, chlorite (?) and palagonite (?).

Cross-cutting sediments of the Katrol series and the Lower Bhuj series is another trap dyke which extends southeast from the west edge of the map area for 1⅞ miles to a point about one mile northeast of Wada (Plate 1). At a point 1¾ miles north of Wada, the dyke is 8 feet wide and at 1 1/8 miles northeast of the village, it is 17 feet wide with a strike N. 45° W. and a dip 72° northeast. The dyke rock is generally a dense fine-grained black basalt.

About a furlong from the southeast end of this trap dyke and separated from it by a 200-foot offest toward the southwest is a ferruginous-siliceous sandstone dyke which also trends southeast, interrupted by a short southwesterly offset, for about one mile (Plate 1). In a knoll about one mile east-northeast of Wada the dyke is about 20 feet wide with a strike of N. 45° W. and a dip of 80° northeast. The rock in the dyke zone consists of quartzose sandstone much like the adjacent country rock that has been highly impregnated with and indurated by secondary silica and iron oxides or hydroxides. As a result of the induration the rock in the dyke zone is much more resistant to weathering than the adjacent country rock.

Two other ferruginous-siliceous sandstone dykes crop out in well marked ridges about ½ mile east and northeast of Wada (Plate 1). Both dykes cross-cut Katrol and Lower Bhuj sediments and intersect one another at angles of about 15 degrees. In the area ½ mile east-northeast of Wada one dyke strikes N. 40° W. and dips 65° southwest and the other strikes N. 25° W. and dips 65° southwest. The iron and silica impregnated sandstone of the dyke zones ranges from a few feet to as much as 40 feet wide. Each of the dykes is approximately 1½ miles long.

East of Pantia about 5 furlongs is the intersection of two ferruginous-siliceous sandstone dykes which cross each other at about 15 degree angles. Both of these dykes also intersect the Sidungra trap dyke about 5½ furlongs southeast of Pantia (Plate 1). The sandstone dykes both trend in a southeasterly direction for about 2½ miles and in each the southeast segment is offset toward the southwest. The southeast segment of one of the dykes strikes N. 40° W. and dips 75° northeast. Composing this dyke segment is a non-descript rock which appears to be an altered trap. Elsewhere along the dyke lines the rock is medium to coarse quartzose sandstone which has been indurated by the introduction of secondary silica and iron oxides in zones from a few feet up to about 15 feet wide.

Outcrops of trap sills have not been distinguished in the Anjar-Khedoi region. However, in well 792, which is about ½ mile southeast of Nigal, trap is reported to have been encountered under sandstone at a depth of about 55 feet. This trap may be part of a trap sill intruded into the Lower Bhuj series.

The trap dykes and associated ferruginous-siliceous sandstone dykes of the Anjar-Khedoi region are genetically related to one another. Evidently basalt magma was intruded in some places along crustal fractures to form trap dykes but in other places silica and iron oxides were deposited from hydrothermal solutions in the sandstone country rock along fractures to form ferruginous-siliceous sandstone dykes. The basalt and the iron and silica bearing solutions thus probably originated from a common magma. Moreover, the dykes are also considered to belong to the same eruptive period as the Deccan trap flows to which they probably acted as feeders from the magma chamber.

Insofar as can be judged from the ground-water hydrology, the indurated zones along the ferruginous-siliceous sandstone dykes are generally too thin and discontinuous to act as effective barriers to the movement of ground water in the Anjar-Khedoi region. On the other hand the relatively wide and continuous Sidungra trap dyke is evidently a potential barrier to ground-water movement through the Upper Bhuj sandstones. The water-table contours of Plate 1 indicate a generally west to east ground-water movement subparallel to the trend of the dyke. Locally, however, north-south components of ground-water movement may be affected by the presence of the dyke.

CRETACEOUS SYSTEM

UPPER BHUJ SERIES

Physical character

All of the Khamra lowland with the exception of the northwest salient between the Nigal upland and the Ratnal Hills is underlain by slightly to moderately consolidated fluviatile sediments of the Upper Bhuj series (map symbol, Kbu, in Plate 1). In addition Upper Bhuj sediments crop out or lie near the surface in the Viri lowland and contiguous inliers as well as in the Mathada inlier about 2 to 3 miles west-southwest of Khedoi Nala (Plate 1).

During the course of the ground-water investigation for the Kandla Port water supply 5 deep exploratory borings were put down in outcrop areas of Upper Bhuj sediments. The locations of these borings are shown in Plate 1 and detailed stratigraphic descriptions of the sediments encountered are given in Appendix 8. The borings have shown that the sediments of the

Upper Bhuj series are predominantly sandstones with minor partings of silty shales, shales and siltstones. As indicated by the borings put down near Viri (A_3), Khedoi (K_2) and Nagalpur (N_2), sandstones form about 90 to 95 per cent. of the upper and middle parts of the Upper Bhuj sequence. The lower part of the Upper Bhuj as indicated by the logs of exploratory borings near Bhadroi (BH_1) and Khamra (KH_1) is about 83 to 98 per cent. sandstones.

The sandstones of the Upper Bhuj are commonly of medium to coarse-grained texture and of white to buff colour. They consist very largely of quartz grains which in most places are only slightly cemented by fine argillaceous or feldspathic material so that the rocks are generally soft and friable. Locally the sandstones contain thin lenticular streaks of well-rounded quartz pebbles and clay galls. Current bedding is highly developed in Upper Bhuj sandstones and in many places obscures normal stratification. Intercalated with the soft and friable sandstones are thin beds of compact silty or sandy shales, shales, micaceous siltstones and ferruginous sandstones whose colours range from white and gray to pale reddish and yellowish brown and purple. In places the shales contain poorly preserved impressions of plants and thin carbonaceous layers.

Extensive exposures of Upper Bhuj sediments are not common owing to low relief and the prevailing softness of the rocks. However, typical white, friable medium to coarse-grained current-bedded sandstone crops out in the watercourse about 1⅛ miles east of Khamra, along Sang River about 1⅝ miles north-northeast of Khamra and along Khedoi Nala. In open step well 23, about one mile southeast of Pantia some 40 feet of buff to light gray coarse to very coarse sandstones are exposed. The cementing material is argillaceous or feldspathic. Current bedding is well developed with current sets dipping 25 degrees west. The attitude of the normal stratification is horizontal. The finer textured sediments of the Upper Bhuj are well exposed in low buttes about one-half mile north of Loharia. Here are some 20 feet of finely laminated, gray, micaceous siltstone and shale bearing poorly preserved leaf impressions. Thin gray siltstones are also exposed in the large tank west of Khamra base of the Upper Bhuj is marked by a thick, massive, soft, and in a watercourse about one-half mile south of the village are outcrops of gray, clay shale containing plant fossils. The friable, medium to coarse-grained, pale gray to white, current-bedded sandstone which can be traced discontinuously around the southern and eastern base of the Nigal upland as well as around the base of Samparda ridge. This member apparently correlates in exploratory boring (BH_1) with sandstone member (S) which is 105 feet thick and in boring (KH_1) with member (K) which is 74 feet thick (*See* Appendix 8).

Judging from the dip and width of outcrop in the Anjar-Khedoi region, the Upper Bhuj series attains a maximum thickness of about 1,000 feet. The Upper Bhuj is probably thickest in the central and southern parts of the map area where it is covered by the Deccan trap. Toward the north, northeast and northwest the Upper Bhuj gradually decreases in thickness and finally pinches out. Thus along the axis of the Bhadroi syncline the Upper Bhuj thins out gradually northward to a feather edge and is apparently absent in the northwest salient of the syncline which lies north of the Nigal upland and south of the Ratnal Hills (Plate 1). At exploratory boring (KH_1), which is about 5 furlongs east of Khamra, the Upper Bhuj sequence was penetrated to a depth of 387 feet and at boring (BH_1), 1 5/8 miles southeast of Bhadroi, to a depth of 385 feet. However, in the Nagalpur boring (N_2), 5 furlongs east of the village, Upper Bhuj sediments were penetrated by the drill to a depth of 700 feet and at the Khedoi boring (K_2), one furlong north-northwest of Khedoi Mota, to a depth of 705 feet. Exploratory boring (A_3), which lies in the Viri inlier about 1½ furlongs south of the village, began at the base of the Deccan trap and passed through a thickness of 850 feet of Upper Bhuj sediments (*See* Appendix 8).

The Upper Bhuj sediments are involved in the folds of the Nigal upland, Samparda ridge and the Khamra lowland. Around the flanks of the dome of the Nigal upland, Upper Bhuj strata show gentle dips ranging from 2 to 6 degrees that are southerly near Loharia and then swing southeasterly to easterly and northeasterly near Bhadroi. These dips flatten to one degree or less in the Bhadroi syncline and in most of the rest of the Khamra lowland. On the northern flank of the Samparda anticlinal ridge Upper Bhuj strata have steep northerly and northeasterly dips of 25 to 65 degrees and on the southern flank dips are southerly and south-westerly at about 5 to 10 degrees.

Water-bearing properties

The soft friable sandstones of the Upper Bhuj series are moderately to very permeable and contain the most productive water-bearing beds in the Anjar-Khedoi region as well as in much of central and eastern Kutch. Moreover, the Upper Bhuj water-bearing strata constitute a reservoir from which a considerable quantity of water can be recovered perennially for public supplies, irrigation and other purposes. As shown by the logs of deep exploratory borings given in Appendix 8 a number of thick water-bearing sandstones occur in the Upper Bhuj series at depths ranging from near the surface to 850 feet below land surface. However, because these sandstones vary considerably in texture, compaction, cementation and thickness their water-yielding capacity is not constant from place to place nor at different depths below land surface.

The relative water-yielding capacities of Upper Bhuj sandstone aquifers at different depths in 7 exploratory borings are shown comparatively in Table 11. This table summarizes pertinent data on yield tests of water-bearing zones given in Appendix 11.

TABLE 11

Exploratory boring No.	Interval of open hole tested (feet below land surface)	Footage of water-bearing sandstone tapped by open-hole section	Specific capacity of open-hole interval (Imp. gal./min./ft. of drawdown)	Capacity index (1) (specific capacity per foot of open hole)	Capacity index(2) (specific capacity per foot of water-bearing sandstone exposed in open-hole section)
(1)	(2)	(3)	(4)	(5)	(6)
A_2 . .	60—182	122	33·0	0·19	0·19
AA_1 .	0—95	45	30·0	0·33	0·67
BH_1 .	90—225	165	9·8	0·08	0·06
	282—385	105	4·1	0·04	0·04
K_2 . .	0—75	48	11·6	0·17	0·24
	102—160	55	29·4	0·50	0·53
	190—325	115	19·7	0·15	0·17
	337—705	322	13·8	0·04	0·04
KH .	40—285	245	15·6	0·06	0·06
	315—420	92	7·6	0·07	0·08
N_1 . .	172—300	118	3·2	0·025	0·03
N_2. .	30—80	30	1·9	0·04	0·06
	83—225	142	20·1	0·14	0·14
	360—520	160	0·6	0·06	0·06
	360—700	225	26·5	0·08	0·08

As suggested by the capacity indices of columns 5 and 6 in Table 11, water-bearing sandstones in the upper part of the Upper Bhuj series generally appear to have considerably higher water-yielding capacity than aquifers in the middle and lower parts of the Upper Bhuj. Thus the highest capacity indices (columns 5 and 6, Table 11) are recorded in borings A3, AA5 and K2 all of which start in the Upper Bhuj series at or near the base of the Deccan trap. Borings N1 and N2 which tap aquifers in the middle part of the Upper Bhuj series show somewhat lower capacity indices as do borings BH1 and KH1 which tap aquifers in the lower part of the Upper Bhuj. The lower water-yielding capacity of the middle and lower aquifers of the Upper Bhuj is attributed to a greater degree of compaction and/or cementation than prevails in the upper aquifers.

Generally the water in Upper Bhuj sandstones which lie within 75 feet of the land surface is unconfined and the upper surface of the zone of saturation is marked by a water table. Locally, however, where siltstones, or shales lie near the surface, water in the shallow water-bearing sandstones may be partly confined under hydrostatic pressure by these relatively impervious beds. Water in the deeper sandstone aquifers, that is, greater than 150 feet is generally confined, although imperfectly, by lenticular beds of impervious siltstone and shale. However, because these impervious beds are relatively thin and discontinuous, it is believed that the several aquifers of the Upper Bhuj series are generally interconnected, although indirectly. Consequently these aquifers probably function essentially as a single hydrologic unit.

In some places in the Anjar-Khedoi region the static level of the confined water in deep aquifers has been observed to be higher than the water table of shallow aquifers and the confined water may be said to have artesian pressure head. In other places the static water level has been observed to be lower than the water table and the confined water may be said to be artesian with subnormal pressure head and the water table is semiperched. In exploratory boring AA5 (Appendix 11) the static water level in aquifers above a depth of 95 feet was 3·5 feet below land surface but in aquifers between 125 and 154 feet the static water level rose to 1·0 feet below land surface. On the other hand in exploratory boring N2 (Appendix 11) aquifers from the surface down to a depth of 325 feet had a static level 31·0 feet below land surface but in aquifers between 360 and 700 feet the level dropped to 33·7 feet below land surface. The static water level of 33·0 feet in exploratory boring KH1 (Appendix 11) did not change appreciably down to a depth of 700 feet. Thus the differences of hydrostatic head between deep and shallow aquifers of the Upper Bhuj as indicated by the exploratory borings do not generally appear to be greater than about 3 feet in the Anjar-Khedoi region.

Locally, in the Anjar-Khedoi region Upper Bhuj aquifers contain water under sufficient head to produce flowing wells. Thus when exploratory well A3 near Viri was first completed in March 1951 as a production tube well at a depth of 220 feet, there was a slight flow of less than one gallon a minute at the land surface. This flow has since ceased. Well 29, which lies about one-quarter mile south of Anjar, was originally dug to a depth of 30 feet in Deccan trap and then deepened by boring into underlying Upper Bhuj sandstones to a total depth of about 135 feet. When observed in May 1951 the well was flowing about one gallon a minute at 2 feet above land surface. Elsewhere in the Anjar-Khedoi region, Upper Bhuj aquifers are not known to produce flowing wells.

CRETACEOUS AND JURASSIC SYSTEMS

Lower Bhuj series

Physical character

The Lower Bhuj series comprises slightly to moderately consolidated fluviatile and estuarine sediments (map symbol, JKbl, Plate 1) which crop out along the flanks of the Nigal upland, in the northwest salient of the Khamra lowland and on the flanks and crest of Ratnal Hills and Samparda ridge (Plate 1). Elsewhere in the Anjar-Khedoi region, the Lower Bhuj is moderately to deeply buried beneath a cover of Upper Bhuj sediments and younger rocks.

Sediments of the Lower Bhuj series include intercalated fine to medium-grained, current-bedded sandstones, variegated silty shales and shales, micaceous siltstone and flaggy sandstones. Exploratory borings (BH1) near Bhadroi and (KH1) near Khamra penetrated Lower Bhuj sediments between depths of 385 to 700 feet and 387 to 700 feet, respectively beneath a cover of Upper Bhuj. The lithologic character of Lower Bhuj sediments penetrated by these borings is described in some detail in Appendix 8. In the Bhadroi (BH1) boring about 40 per cent. of the Lower Bhuj sediments penetrated are arenaceous and 60 per cent. are argillaceous. On the other hand in the Kharma (KH) boring some 80 per cent. of the Lower Bhuj sediments are arenaceous and only 20 per cent. argillaceous. The current-bedded sandstone members of the Lower Bhuj are in most places soft and friable but in other places moderately indurated. The cementing material is commonly argillaceous or feldspathic and also contain iron oxides which impart a reddish to yellowish tint to the rock. The colours of the sandstones range from white and buff to purple, red and brown. Intercalated with the sandstones are laminated shales and silty shales whose colours range from white, grey and purple to pink and lavender. Poorly preserved plant remains occur at places in the sediments and occasionally thin streaks of lignite or carbonaceous material are found. Micaceous siltstones and flaggy sandstones are also present among Lower Bhuj sediments and range in colour from pale yellow to brown, buff and purple. Finely comminuted particles and flakes of mica are abundantly present along the bedding planes of the siltstones. Characteristic of Lower Bhuj outcrops are thin-bedded sandstones cemented by ferruginous material which give a dark red or purple colour to the rock. Such ferruginous layers form hard resistant ledges which are relatively continuous and which effectively delineate in outcrop the strike of Lower Bhuj sediments around the Nigal dome and the miniature domes and saddles of the anticlines of Ratnal Hills and Samparda ridge.

The sediments of the Lower Bhuj series crop out extensively in the Nigal upland, the Ratnal Hills and Samparda ridge owing to moderate dissection and to the presence of resistant strata. At Nigal in the basal part of the Lower Bhuj are outcrops of thin-bedded medium to fine-grained soft yellowish brown sandstone. About one-half mile south of Nigal this sandstone is overlain by thin-bedded, laminated gray shales with poorly preserved leaf impressions. Similar gray shales of somewhat higher stratigraphic position in the Lower Bhuj crop out in a stream bed about 6 furlongs southeast of Nigal. Still higher in the stratigraphic section are about 50 feet of thin-bedded, brown, fine-grained, ferruginous sandstones intercalated with bands of gray shale and siltstone that crop out in a butte about one furlong southwest of Malingna. The upper part of the Lower Bhuj sequence is well exposed along a sharp bend in Sang River about 6 furlongs southeast of Malingna. Here the top of the Lower Bhuj is marked by a zone of gray carbonaceous and micaceous laminated sandy shale and shale containing plant fossils intercalated with beds 5 to 10 feet thick of buff to brown current-bedded sandstone. This zone which is about 30 to 40 feet thick evidently corresponds to members (T) through (W) of exploratory boring (BH1) and members (L) through (P) of boring (KH1), (Appendix 8). The zone is traceable for about 4 miles along the southern and eastern base of the Nigal upland and is also present around the basal slopes of Samparda ridge. Although many poorly preserved impressions of plants were found by the writers in sediments of this zone, none of these fossils has proved suitable for age determination. From core samples taken in exploratory boring (KH1), palaeontologic examination was made in the Geological Survey of India laboratory of carbonaceous material from depths of 404 and 422 feet, which correspond to members (N) and (P), respectively (Appendix 8). According to Dr. K. Jacob (personal communication) only gymnosperm spores are present in the material and an uppermost Jurassic or lower Cretaceous age is probably indicated.

The Lower Bhuj series is absent on the crest of the Nigal upland because of erosion. However, along the southern and eastern base of the upland, the Lower Bhuj attains a thickness estimated from the dip and width of outcrop to be about 500 feet. Of this thickness some 315 feet were penetrated between depths of 385 and 700 feet in exploratory boring (BH1) and in boring (KH1) the drill passed through 313 feet of Lower Bhuj sediments between depths of 387 and 700 feet.

The folds of the Nigal upland, the Ratnal Hills, Samparda ridge and the northwest salient of the Khamra lowland are effectively delineated by resistant ferruginous ledges of Lower Bhuj strata. Thus Lower Bhuj sediments dip quaquaversally around the large structural dome of the Nigal upland with southerly and easterly dips of one to 5 degrees on the south and east and steeper northerly dips of 5 to 10 degrees on the northern flank. On a Samparda ridge outcropping Lower Bhuj strata delineate 6 small structural domes separated by narrow structural saddles along the crest of an anticline. Dips in Lower Bhuj strata on the northern flank of this fold are northerly at about 20 to 75 degrees and on the southern flank are gentler at some 5 to 15 degrees toward miniature structural domes with intervening saddles along the south.

Water-bearing properties

The shale, siltstone and compact fine-grained sandstone members of the Lower Bhuj are not particularly pervious and hence cannot be expected to yield much water to wells. On the other hand the friable medium to coarse-grained sandstone members are permeable and yield moderate supplies of water to wells put down in outcrop areas, that is, in the Nigal upland, the Ratnal Hills, Samparda ridge and the northwest salient of the Kharma lowland. However, Lower Bhuj aquifers are not generally so productive as those of the Upper Bhuj but are nevertheless important, particularly in areas where Upper Bhuj strata are absent. Water-bearing sandstones in the Lower Bhuj were also encountered in exploratory borings (BH1) and (KH1) beneath fairly thick cover of Upper Bhuj sediments. In boring (BH1) the Lower Bhuj was penetrated between 385 and 700 feet and in (KH1) between 387 and 700 feet. The relative water-yielding capacities of Lower Bhuj aquifers at different depths in these 2 borings are shown comparatively in Table 12 which summarizes pertinent data or yield tests of water-bearings zones given in Appendix 11.

TABLE 12

Exploratory boring No.	Interval of open hole tested (feet below land surfaces)	Footage of water-bearing sandstone tapped by open-hole section	Specific capacity of open-hole interval (Imp./gal./min./ft. of draw down)	Capacity index (1) (specific capacity per foot of open hole)	Capacity index (2 (specific capacity per foot of water-bearing sandstone exposed in open-hole section)
BH_1 .	282—590	140	5·5	0·02	0·04
	282—700	170	5·3	0·01	0·03
KH_1 .	315—525	156	5·9	0·03	0·04
	315—700	316	10·8	0·03	0·03

It is noted that the capacity indices of Lower Bhuj aquifers shown in Table 12 are slightly lower than the indices for the lower part of the Upper Bhuj in the same borings given in Table 11. Thus an even greater degree of cementation and/or compaction appears to prevail in Lower Bhuj sandstone aquifers than in the middle and lower parts of the Upper Bhuj.

JURASSIC SYSTEM

KATROL SERIES

Sediments of the Katrol series (map symbol, Jk. in Plate I) crop out in and around the margins of a large elliptical depression (Sur Tallao) which lies on the crest of the structural dome of the Nigal upland. The Katrol sediments have been exposed by the erosional removal of a formerly continuous cover of Lower Bhuj sediments over the crest of the dome. The outcrop area of Katrol sediments is roughly elliptical in shape and extends some 2½ miles from east to west and 1½ miles from north to south (Plate 1). Typically the Katrol sediments consists of thin beds of very hard, brown, blocky sandstone at the top underlain by soft yellowish brown and gray gypseous clay shales. Characteristically the shales contain thin veinlets, stringers and disseminated crystals of gypsum and generally weather down into smooth rounded slopes or low-lying ground.

Only about 175 feet of the uppermost part of the Katrol series are exposed in the outcrop area but elsewhere in Kutch the Katrol series attains a thickness of more than 1,000 feet. The Katrol strata in the outcrop area have quaquaversal dips conforming to the structure of the Nigal dome. Thus on the crest of the dome the dips are flat, on the north they are northerly at about 2 to 8 degrees, on the east they are easterly at about 5 to 7 degrees and on the south, southerly at 2 to 5 degrees.

No wells were observed in Katrol sediments during the present investigation. However, it is probable that the shales and hard indurated sandstones of the Katrol series are relatively impervious and probably would yield only meagre supplies of brackish to salty water to wells put down in the outcrop area.

GEOLOGIC STRUCTURE

General features

As suggested by Auden (1951, p. 116) Kutch should be considered an eastern extension of the mobile orogenic belt of Sind and Baluchistan rather than a part of the unfolded and stable peninsular foreland as has hitherto been supposed. In this orogen Mesozoic and Tertiary terrestrial and marine sediments and the Deccan trap have been involved in folding movements which began in middle Tertiary time and continued intermittently into the Quaternary. The great Kutch earthquake of 1819 and lesser quakes in 1844, and 1845 (Wynne, 1872, pp. 29-47) suggest that these stresses may still be operative in Kutch. The general trend of anticlinal folds in Kutch is northwest-southeast in the western part of the state but swings to east-west in the eastern part. This change in strike may be related to the shape of the peninsular shield which flanks the progenic belt on the north. Moreover, along major anticlinal axes the folds are segmented in an en echelon manner which Auden (1951, pp. 113-114) suggests may have been caused by oblique tear faulting. Typically the anticlinal folds of Kutch are assymetrical with gentle dips on the southerly flanks and steep dips on the northerly flanks which in places are bound by strike faults. Also typical of Kutch folds are remarkable small-scale or miniature structural domes and saddles aligned along anticlinal axes like beads on a string. The trends, en echelon arrangement and assymetrical shape of Kutch folds suggests (Auden, 1951, p. 113 ; 1952, p. 57) that the forces acted in couples against a western projection of the Indian peninsular shield represented by the Pre-Cambrian crystalline rocks of Nagar Pakar along the northern margin of the Great Rann of Kutch.

Folds

The principal structural features of the Anjar-Khedoi region are the Nigal dome, the Ratnal anticline, the Bhadroi syncline. the Samparda anticline, the Mita Nadi syncline, the Warsamedi anticline, the Shinaya anticline and the Mathak anticline. All of these folds are indicated by appropriate structural symbols in Plate 1 and the shape and outlines of structural features within the folds are shown by strike lines of outcropping strata traced from aerial photographs. The Nigal dome which lies in the northwest part of the map area (Plate 1) is perhaps the most conspicuous structural feature of the Anjar-Khedoi region. This dome extends some 3½ miles from north to south and 4½ miles from east to west and has an axis which trends and plunges east toward the Bhadroi syncline. The dome forms a large elliptical or spoon-shaped " blister " at the eastern terminus of the great Chaduva (Katrol) Hills anticline which extends through central Kutch in an east-west direction for some 40 miles. From the crest of Nigal dome around Sur Tallao, Bhuj and Katrol strata dip quaquaversally—first northerly and easterly into Bhadroi syncline, then southerly into the Kharma lowland and finally, westerly into a structural saddle on the axis of the Chaduva Hills anticline. The southerly and easterly dips on the dome generally range from 2 to 7 degrees with northerly dips slightly steeper from 3 to 10 degrees.

In the north-central part of the Anjar-Khedoi region is the doubly plunging Samparda anticline whose axis trends east-southeast for some 3¾ miles. Along the crest of this anticline is a chain of 6 miniature domes separated from one another by narrow structural saddles. The domes which are of circular to elliptical outline range from about 2 to 5 furlongs in diameter and each shows quaquaversal dips in Lower Bhuj strata. On the north flank of Samparda anticline dips are steeply northerly at 20 to 75 degrees but on the south flank southerly dips are more gentle at about 5 to 15 degrees.

A low gap about 3 furlongs wide separates the northwest end of Samparda anticline from the east end of Ratnal anticline which is also a doubly plunging structure. The Ratnal anticline whose axis trends east-west extends some 4 miles along the northern margin of the map area and ends about 3 furlongs east of the anticline are 4 miniature domes ranging from 2 to crest of the anticline are 4 miniature domes ranging from 2 to 5 furlongs in diameter and each is marked by quaquaversal dips in Lower Bhuj strata. Like the Samparda structure dips on the north flank are steeply northerly at 20 to 60 degrees and southerly on the south flank at 5 to 10 degrees.

Lying between the Nigal dome on the south and southeast and the Ratnal and Samparda anticlines on the north and northwest is the Bhadroi syncline (Plate 1). Near the northwest corner of the map area the axis of the syncline trends south for about half a mile but then swings sharply to the east around the west end of Ratnal anticline. The axis of the syncline then trends easterly for some 3½ miles between the Nigal dome and Ratnal anticline and then swings to a southeasterly trend for 2½ miles between Samparda anticline and the Nigal dome. About 1¼ miles east-southeast of Bhadroi the syncline plunges and opens out to the southeast (Plate 1).

The Warsamedi anticline and the Mita Nadi syncline lie in the northern part of the map area and involve the Deccan trap with its capping laterites and the overlying sediments of the Manchhar series. Both of these structures are doubly plunging. The axis of the Warsamedi anticline trends east-southeast for about 6½ miles and the sub-parallel Mita Nadi syncline, for about 3 miles. On both limbs of the syncline dips are less than 5 degrees. On the other hand the southerly dips on Warsamedi anticline are generally less than 8 degrees but northerly dips are generally greater than 10 degrees.

In the south-central part of the map area is the Shinaya anticline which involves the Deccan trap and overlying sediments of the Manchhar series. This fold is a relatively open structure whose axis trends southeast for about 5 miles. It opens and gradually dies out to the northwest but plungs sharply to the southeast near Shinaya village. The dips in the trap around the flanks of the fold generally range from about 2 to 5 degrees.

The Mathak anticline which lies in the southeast part of the area follows a rather tortuous axial line which trends from east-northeast through east to northeast (Plate 1) for a distance of about 3½ miles. This flexture has a very sharp and narrow crest and apparently involves only Manchhar sediments. Dips on opposite sides of the axial line of the anticline range from 10 to 40 degrees but these generally flatten abruptly to 2 degrees or less within a furlong of the crest.

Faults

Faults occur in the Anjar-Khedoi region to the northeast of Samparda anticline, near Khambhra and about a mile to the northwest of Mathak (Plate 1). Following the northeast flank of Samparda anticline are two sub-parallel strike faults whose traces on the surface are about 2 furlongs apart. These faults are here designated the north Samparda and south Samparda faults. On the northeast flank of Samparda anticline both faults follow a west-northwest trend for some 4 miles (Plate 1) but near a point about 1¼ miles northwest of Samparda village the trace of the north fault swings to the west and crosses that of the south fault which also assumes a more westerly trend just north of the map area. The south Samparda fault truncates obliquely the edges of the dome and saddle structures in Samparda anticline and brings the basal section of the Upper Bhuj series on the north side of the fault down against the upper part of the Lower Bhuj on the south. The south Samparda fault thus appears to be a normal gravity fault with the downdropped side to the north. However, because no good exposures of the fault plane have been observed, the possibility exists that the fault may be a high angle reverse fault, which type is not uncommon in other parts of Kutch. The throw on the fault about 6 furlongs east of Samparda is of the order of about 200 feet but this gradually dies out to the east-southeast along the trace of the fault. Near the north edge of the map area the trace of the south Samparda fault swings to the west and beyond the map area merges with the " Great Strike Fault " or Charwar-Katrol fault which trends east-west along the northern base of the Chaduva (Katrol) Hills anticline. According to Wynne (1872, p. 175) the maximum throw on the Charwar-Katrol fault may be of the order of 2,500 feet in central Kutch.

On the northeast flank of Samparda anticline, the north Samparda fault is separated from the south fault by a fault slice of Upper Bhuj sediments about 2 furlongs wide. The north fault brings the Deccan trap on the north side down against the upper part of the Upper Bhuj on the south side. The maximum throw on the north fault is probably no greater than 200 feet.

About one mile northwest of Samparda village the fault zone and adjacent rocks are well exposed in a railway cutting. Here the fault trace trends westerly and the dip of the silicified zone along the fault plane is 65 degrees north. Upper Bhuj sediments on the south side of the fault are here in fault contact with the Deccan trap on the north. Near its north-western terminus the north Samparda fault is marked by a vertically dipping silicified shear zone which truncates the end of the Ratnal Hills anticline, and brings Upper Bhuj sediments into fault contact with the Lower Bhuj strata.

As shown in Plate 1, minor faults occur in the southern part of the map area near Khambhra and Mathak. The Khambhra fault trends east to east-southeast for about 2 miles. On the south side of the fault the basal conglomerate member of the Manchhar series and the Deccan trap have been upthrown against the mottled sandstone member of the Upper Manchhar on the north side. Near its eastern end the fault dies out in a sharp little anticlinal flexture and at Khambhra the western end dies out in an assymetric anticlinal nose in the Deccan trap. The maximum throw on the fault is estimated to be between 25 and 50 feet. The Mathak fault which trends southwest for about a mile brings the basal conglomerate member on the southeast up against the mottled sandstone member on the southwest. The maximum throw on the fault is less than 25 feet.

Epochs of deformation

All of the folds of the Anjar-Khedoi region, with the possible exception of Mathak anticline, should probably be considered satellite or terminal structures on the eastern end of the major Chaduva (Katrol) Hills anticline of central Kutch. These folds, along with the major anticlines of Kutch, resulted from compressive stresses which probably began in Miocene time and continued intermittently into the Pleistocene and even Recent. Inasmuch as sediments of probable late Pliocene age are also involved in the Warsamedi and Mita Nadi folds, evidence is strong that in the Anjar-Khedoi region the compressive stresses were still active in the Pleistocene.

Initial movements on the Charwar-Katrol fault and its eastward extensions in the north and south Samparda faults of the Anjar-Khedoi region probably began toward the end or shortly following the Miocene epoch of folding and continued in the Pliocene. However, inasmuch as an apparently undisturbed tongue of late Pliocene Manchhar sediments partly overlaps the north Samparda fault, no Quaternary movement on this fault seems indicated. On the other hand movements on the Mathak and Khambhra faults and the Mathak anticlinal fold which involve the youngest sediments of the Manchhar series have evidently occurred in the Quaternary and possibly even Recent time.

GROUND WATER IN THE BHUJ SERIES

WATER IN UPPER BHUJ AQUIFERS

Form and depth of the water table

The form of the water table of the shallow ground water in permeable sandstones of the Upper Bhuj series is shown by means of 5-foot contours for May 1952 in Plate 1 and for June 1951 and October-November 1951 in Plates 2 and 3, respectively. The contours for June 1951 represent the stage of the water table at the end of the dry season of 1950-51 and the contours for October-November 1951 and May 1952, the stages at the beginning and the end of the dry season of 1951-5. The contours are based on measurements of the altitudes of the water surface in 103 observation wells for Plate 1 and 92 observation wells for Plates 2 and 3. Sea-level datum for these altitudes was determined by spirit levelling. In general the water table slopes in an easterly direction from an altitude of about 300 feet near Loharia to about 155 feet near Anjar. An extensive depression in the water table centered around the Khedoi irrigated tract is defined by the closed 245-foot contour (Plate 1). From Bhadroi toward Anjar the water table has a southeasterly component of slope. The lowest observed altitudes of the water table occur in the inlier just southwest of Anjar as indicated by the closed 155-foot contour in Plate 1.

The contours for June 1951 (Plate 2) show the form of the water table at the end of the 1950-51 dry season which followed the relatively high rainfall of the southwest monsoons of 1949 and 1950. Thus, with considerable carry-over storage in the ground-water body the stage of the water table was probably substantially above the position that would prevail at the end of a dry season following average monsoon rains. The rainfall of the southwest monsoon of 1951 was considerably less than average and hence recharge to the ground-water body was comparatively light. The effects of this recharge were evidently quickly dissipated by artificial and natural ground-water discharge. As indicated by an inspection of Plates 2 and 3, relatively little change in the form of the water table occurred between June 1951 and October-November 1951. Indeed, a slight up-gradient shifting of contours occurred, indicating a small over-all decline of water levels between the two periods of observation. As a consequence of the light recharge of the 1951 monsoon the position of the water table in May 1952 (Plate 1) was generally about 2 to 6 feet below that of the two previous periods of observation. However, the form of the water table is essentially similar to that of June 1951 (Plate 2) and October-November 1951 (Plate 3).

The water table of the shallow ground water in the Upper Bhuj series crops out in springs and seeps or lies within a few feet of the land surface in areas of natural ground-water discharge southwest of Khedoi Nana and south and southeast of Viri as shown by shading in Plates 1-3. The greatest measured depth to water was 83·31 feet at well 687 which lies in the Samparda-Bhadroi irrigated tract about 7½ furlongs west of Samparda. The ranges in and the median depths to water in wells tapping water in Upper Bhuj sandstones in 10 irrigated tracts is shown in Table 13. The ranges and medians given are based on water levels measured in the last half of 1951 and in the first half of 1952.

TABLE 13

Name of irrigated tract	No. of wells observed	Range in depth to water (feet below land surface)	Median depth to water (feet below land surface)
Loharia-Khirasra . . .	17	28—51	32
Khedoi	136	16—44	25
Mathada	13	12—40	34
Pantia	21	32—57	45
Khamra	32	31—51	39
Samparda-Bhadroi . . .	52	57—83	70
Sidungra	31	25—50	37
Nagalpur	83	14—69	36
Viri	24	11—30	20
Anjar.	105	12—50	33

It is noted that deepest water levels occur in the Samparda-Bhadroi irrigated tract and the shallowest, in the Viri and Khedoi tracts. In the other irrigated tracts water levels of moderate depth occur.

Fluctuations of ground-water level

Causes of fluctuations

In the Anjar-Khedoi region the water levels of wells in Upper Bhuj aquifers are known to fluctuate in response

(1) to infiltration from rainfall and from run-off in stream channels ; (2) discharge by evaporation and transpiration ; (3) discharge by pumping from wells and (4) changes in atmospheric pressure. In addition fluctuations not distinguished may occur as a result of other causes.

The fluctuations of the static water level in a well during a period of hours, weeks, months or years may be shown graphically. Such hydrographs show the composite effects of all of the forces that tend to change the ground-water level. However, by selection of particular wells or records for particular periods the hydrographs may discriminate one predominant force which is causing fluctuations of the water level.

The determination of the magnitude and nature of these fluctuations is based on data collected from observation wells. More detailed data are obtained from automatic water-stage recorders which provide continuous records of the position of the water level in a well. Other data are based on periodic weekly, monthly or yearly measurements by steel tape of water levels in selected observation wells.

Seasonal fluctuations related to infiltration from rainfall and stream run-off

Each year a seasonal rise in water levels in wells occurs concurrently with the rain-bearing southwest monsoon which ordinarily lasts from late June until the end of September. Such rises are largely caused by increments to the ground-water body by direct infiltration from rain and to less extent by infiltration from ephemeral streams while in spate. Substantial rises in water levels occur as a result of above-normal rains of the southwest monsoon. Thus, following the 1950 monsoon which recorded rainfall of 24·90 inches at Anjar or more than 1½ times the mean, cultivators report that water levels in most wells rose 6 feet or more in the Anjar-Khedoi region. As shown in Table 2 such rainfall is likely to occur with a frequency of only about once in 12·3 years. Smaller rises are registered in years with normal or below normal precipitation. In years with less than half the mean rainfall, infiltration to ground water may be relatively low. As suggested in Table 2 such low rainfall years may occur with an average frequency of about one in 6·7 years.

During the dry season or northeast monsoon which lasts from October until the following June, a gradual decline of water levels generally occurs as ground-water body is gradually depleted by evaporation and transpiration, by spring flow and by withdrawals from wells for irrigation, public supplies and other purposes. Occasionally, however, infiltration from sporadic rains during the dry season produces small rises in water levels but the effects of such recharge are generally soon dissipated.

The fluctuations of water levels in 7 shallow wells through one yearly cycle (1951-52) are shown by the hydrographs of Figures 2 and 3. Fluctuations in 3 wells located in or near irrigated tracts are shown in the hydrographs of Figure 2 and in Figure 3 the hydrographs of 4 wells remote from irrigated tracts are given. Although the 1951 annual rainfall was only 6·25 inches at Anjar and 10·02 inches at Gandhidham (Adipur), some recharge to Upper Bhuj aquifers occurred and the hydrographs of most of the wells in Figures 2 and 3 show small to moderate rises of water level during June, July and August 1951.

The hydrographs of Figure 2 indicate net rises of water levels during the 1951 monsoon amounting to about 1·7 feet in well 3, about 3·2 feet in well 4 and about 0·6 foot in well 6. Although the net rise can probably be attributed largely to increments to the ground-water body from rainfall penetration, a part of the rise is due to recovery of ground-water levels resulting from cessation or diminution of ground-water draft for irrigation and by evapotranspiration during the monsoon season. The hydrograph of well 3 shows abnormally depressed water levels in late February and early March 1951 owing to heavy withdrawals in prolonged pumping tests at exploratory boring A_3 in the Viri area. When the tests were completed the water levels recovered to their approximate seasonal stage by late March 1951 and thereafter show fluctuations caused by evapotranspiration in a nearby phreatophyte tract and by light withdrawals from wells for irrigation near Viri during the remainder of the 1950-51 dry season. Three marked rises of water level are also noted on the hydrograph of well 3 during the 1951 monsoon corresponding to the three principal rain storms of the season. Well 4 is situated near the middle of the Khedoi irrigated tract and its water level is consequently much affected by daily and seasonal draft of water for irrigation from neighbouring wells. The peak in the hydrograph during April 1951 does not correspond to rainfall but apparently resulted from a temporary slackening in the draft for irrigation. On the other hand, the peaks of July and August 1951 resulted from rainfall penetration and to some slackening in irrigation draft. The hydrograph of well 6

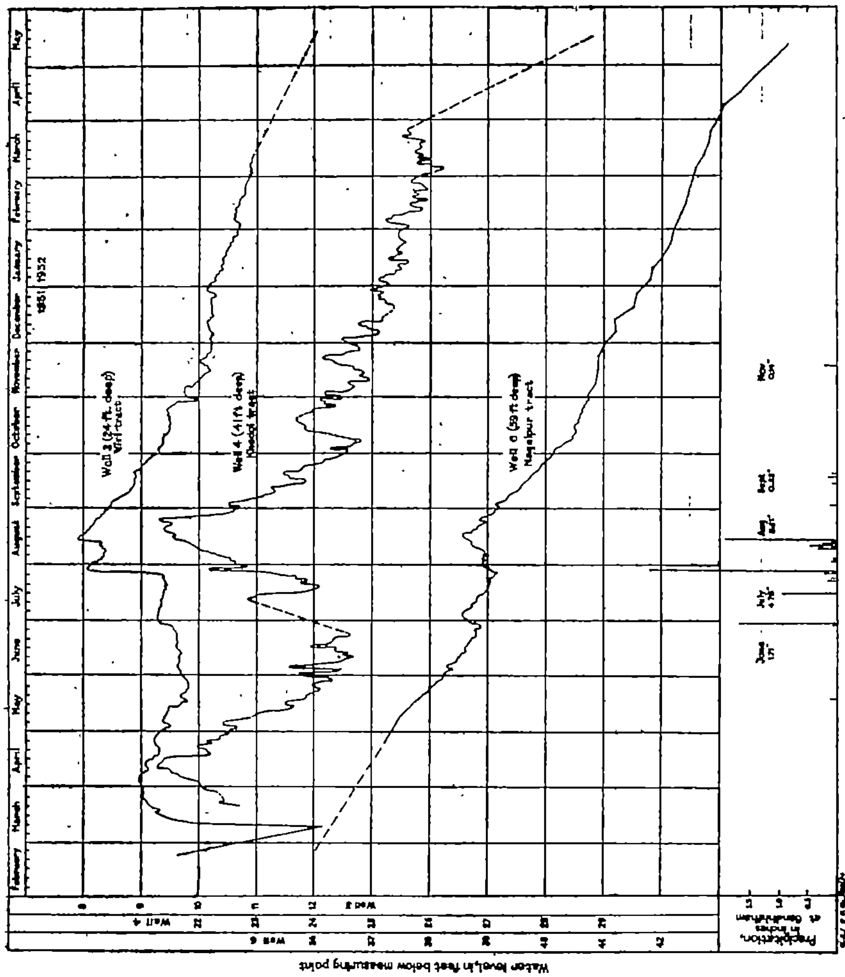


Figure 2. Hydrographs of three shallow wells in or near irrigated tracts showing seasonal fluctuations of water levels, 1951-52

(Figure 2) which is situated near the eastern edge of the Nagalpur irrigated tract shows a rather steady decline of water levels that is attributed to draft from neighbouring irrigation wells. Modest rises in water level in July and August 1951 indicate some recharge from rainfall but this gain was evidently soon dissipated in following months of the dry season of 1951-52.

As shown by the hydrographs of Figure 3 rises of water level during the 1951 monsoon were also registered in some but not all of the observation wells. Inasmuch as the water levels in these wells were not directly affected by withdrawals for irrigation it is probably that the rises indicated can be attributed almost entirely to rainfall penetration. The net rises were less

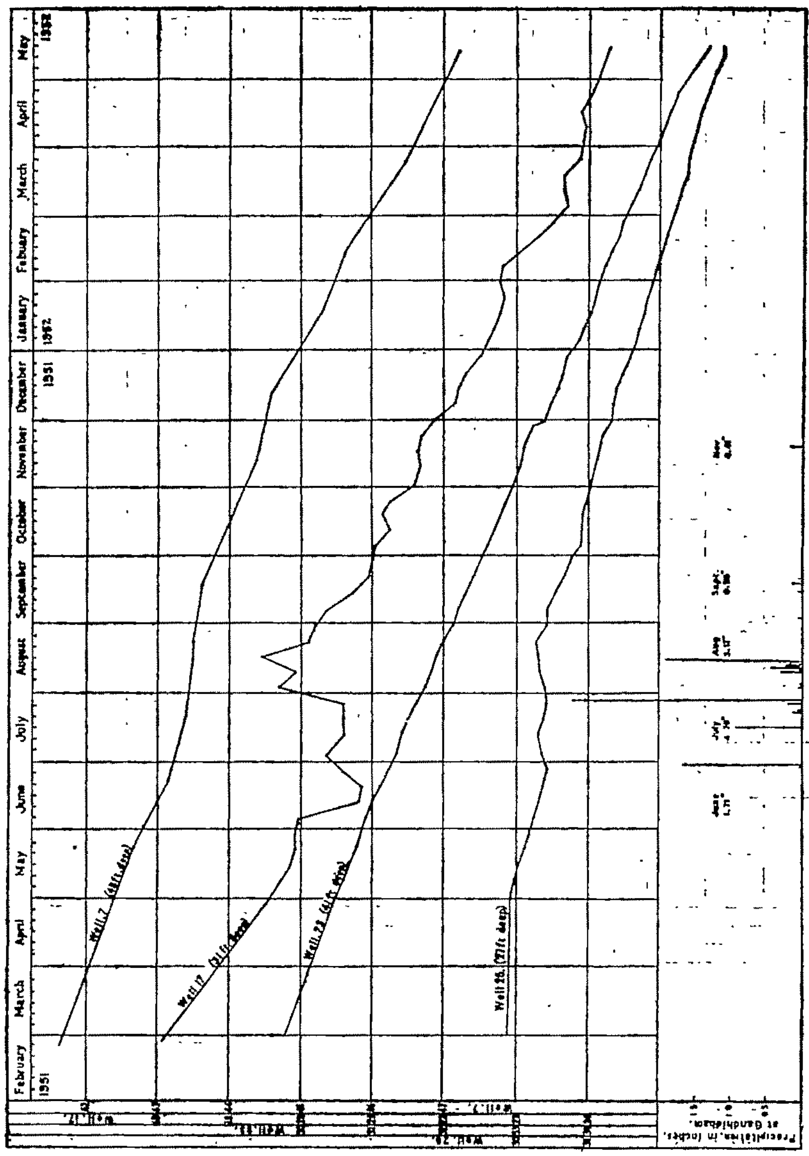


Figure 3 Hydrographs of four shallow wells remote from irrigated tracts showing seasonal fluctuations of water levels, 1951–1952.

than 0·25 foot in wells 7 and 23, but wells 17 and 26 registered over-all rises of about 1·2 feet and 0·4 foot, respectively.

Seasonal fluctuations of water levels through the three one-year cycles from 1951 to 1954 in three deep wells and one shallow well in the Viri area are shown in the hydrographs of Figure 4. All four wells register fluctuations whose general patterns are similar. The amplitude of the fluctuations indicated are greatest in wall A_6 and least in well A_2. As indicated

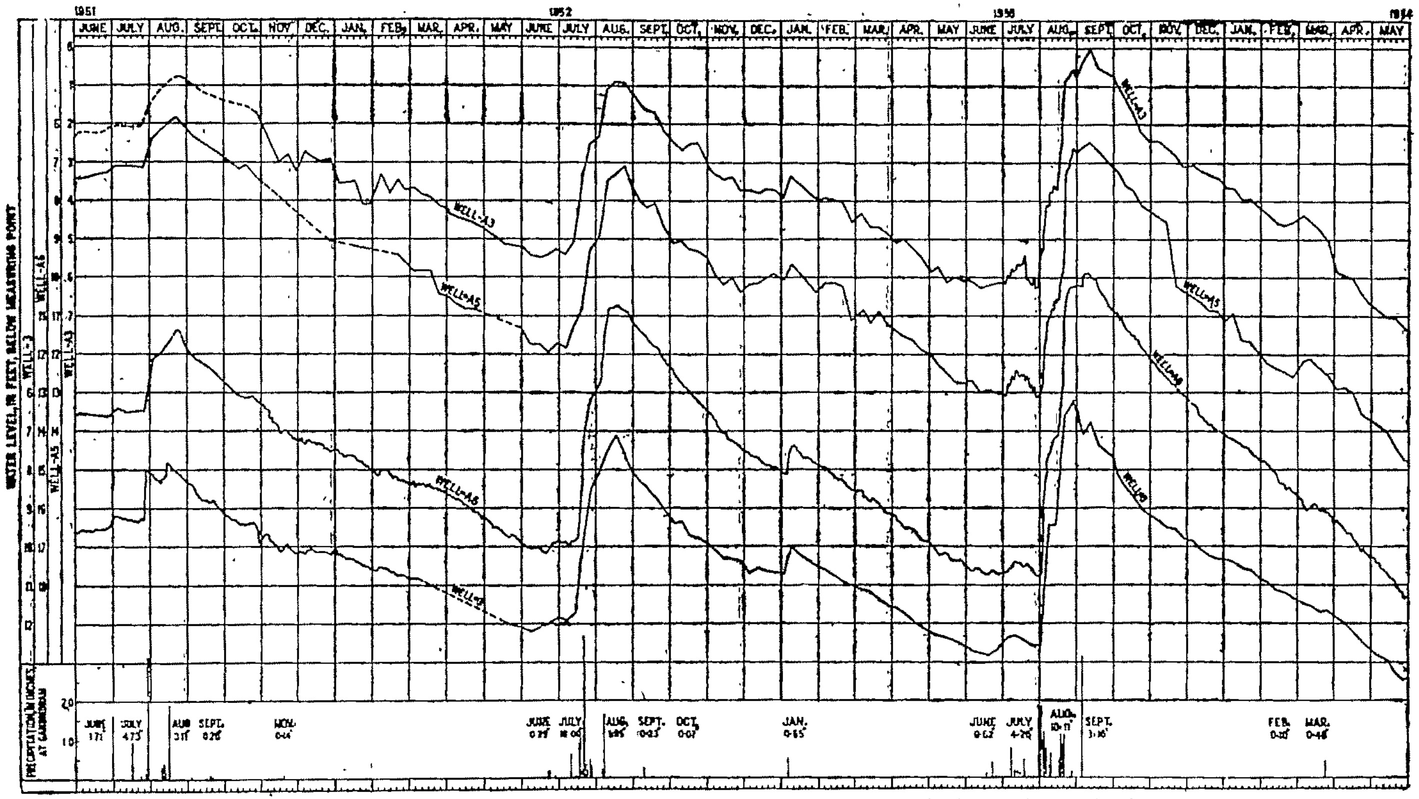


FIGURE 4. HYDROGRAPHS OF THREE DEEP TUBE WELLS AND ONE SHALLOW DUG WELL IN THE VIRI AREA SHOWING FLUCTUATIONS OF WATER LEVELS THROUGH THREE ONE-YEAR CYCLES, 1951-54

by a comparative inspection of the hydrographs and the bar graphs for rainfall there is a marked correlation between rising water levels and the rains of the southwest monsoon. The net over-all rise from the late dry season low in May or June to the monsoon peak in August or September is given comparatively in Table 14 for each of the wells of Figure 4.

TABLE 14

Year		1951	1952	1953
Rainfall, in inches, at Gandhidham during the southwest monsoon.		9·88	12·44	18·15
Net rise of water level, in feet, from dry season low in May or June to monsoon peak in August to September.	Well A_3	1·5+	4·56	6·30
	Well A_5	1·69	4·90	6·73
	Well A_6	2·01	6·39	7·98
	Well 3	1·77	5·10	6·65

Inspection of the hydrographs of Figure 4 also indicates that the late dry season low stage in water level is successively lower each year during the interval, 1951-54. The net amount of this decline for each of the wells of Figure 4 is shown below in Table 15.

TABLE 15

Net decline of water level, in feet.	Well A_3	Well A_5	Well A_6	Well 3
Between June 1951 and June 1952 .	3·13	4·43	3·54	2·41
Between June 1952 and June 1953 .	0·80	1·07	0·61	0·65
Between June 1953 and June 1954 .	1·23	3·34	0·70	0·60
Net over-all decline from June 1951 to June 1954.	5·16	8·84	4·85	3·66

The progressive decline of water levels indicated by Figure 4 and Table 15 is attributed to a succession of two dry years and a slightly above average year (1951-53) following two exceptionally wet years (1949-50). This decline appears to indicate that in the Viri area the net loss of ground-water storage by evapotranspiration, spring discharge and withdrawals for irrigation and for the Gandhidham-Kandla Port supply exceeded the net gain from rainfall penetration during the period of observation. However, it is inferred that this downward trend would be checked if not reversed by one or more successive years with above average rainfall provided the total draft from the ground-water body in the Viri area remains about the same as at present (May 1954).

Owing to deficient precipitation during the southwest monsoon of 1951 there was little or no run-off in the streams of the Anjar-Khedoi region. Consequently it was not possible to observe directly the effects of infiltration from streams on water levels in wells. However, during the abundant rains of the 1950 monsoon there was considerable run-off in the Sang River and other streams of the region. During the run-off period water levels in wells near the Sang are reported to have risen several feet or more probably as a result of infiltration from the stream.

Fluctuations related to evaporation and transpiration

Considerable water may be lost from a ground-water reservoir by evaporation from the soil and by transpiration from plants. According to White (pp. 77-81) evaporation from the soil is comparatively high where the depth to water is less than one foot, comparatively low where the depth to water is more than 2 feet, and probably very low or nil where the water table is more than 8 feet below the land surface. Transpiration most commonly occurs where the water table is within 15 feet of the land surface although some plants which depend on ground-water may send their roots down as deep as 25 feet.

As white (pp. 24-54) and others have shown, certain species of plants commonly send their roots down to the water table or to the capillary fringe and by transpiration induce a diurnal fluctuation in the water-table stage in shallow-water tracts (Plate 1). These plants are phreatophytes or ground-water plants (Meinzer, p. 1) which in the Anjar-Khedoi region include palms, willows, tamarisk, sedges, salt grass and other unidentified species. The two hydrographs of Figure 5 show typical daily fluctuations of water levels in two wells owing to transpiration by date palms, salt grass, willows and other phreatophytes in the area of ground-water discharge about 500 to 2,500 feet south and southeast of Viri. (See also Plates 1, 5, 6 and 7). Also shown is a marked rise in the water levels of both wells

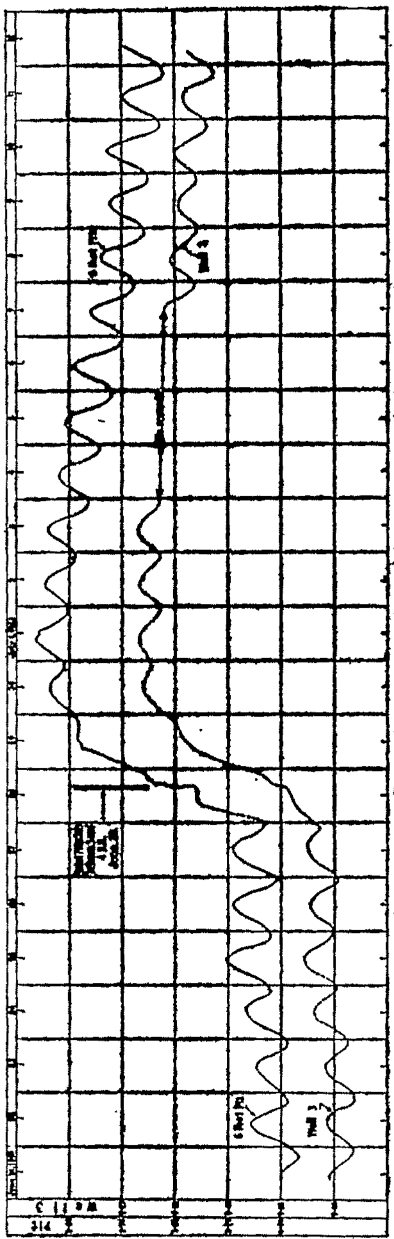


Figure 5. Hydrographs of two wells in the Viri area showing typical daily fluctuations of water levels, June–July 1951

resulting from the first rain of the 1951 monsoon on June 28. Well 3 which is 24 feet deep, is located about 500 feet south of Viri on the north edge of the phreatophyte tract and the pit (6 feet deep) was located near the center of the tract about 1,300 feet south of Viri. As indicated by the hydrographs, the diurnal fluctuations in the 6-foot pit are somewhat greater in amplitude than those in well 3—probably because of the shallower depth of the water table near the pit and of a greater intensity of transpiration in the center of the phreatophyte tract. During the course of one year's (1951-52) water-level observations at well 3, the amplitude of the diurnal fluctuations has been observed to range from about 0·08 foot to 0·02 foot. The greatest amplitudes occur toward the latter part of the dry season when temperatures are high, humidity is low and as a result of these and other factors transpiration is most intense. The amplitudes of least magnitude occur during the southwest monsoon season when the transpiration draft on the water table is partly supplanated by soil moisture available from rainfall penetration. It is to be noted that transpiration is a continuous process in the Anjar-Khedoi region inasmuch as there are no killing frosts during the year.

Evaporation and transpiration are also doubtless important contributing factors in the over-all seasonal lowering of water levels in both deep and shallow wells that takes place during the course of the dry season. The effects of evapotranspiration are most pronounced in the shallow-water tracts but these effects may also be gradually transmitted to areas of deeper water level.

Fluctuations related to pumping from wells

Daily and seasonal fluctuations of the water table in the several cultivated tracts of the Anjar-Khedoi region have also been observed to result from withdrawals of water from wells for irrigation and, in addition, from pumping in tube wells of the Viri area for the Gandhidham-Kandla Port water supply. The hydrographs of **Figure 6** show typical daily fluctuations measured by an automatic water-level recorder on unused well 4 which is located near the center of the Khedoi irrigated tract. The daily lowering of water level from about 6 a.m. to 9 p.m. results from the daytime draft by neighbouring wells. The subsequent rise corresponds to recovery during the night time slack in draft. Minor peaks in mid-afternoon correspond to slack in pumping during meal and rest hours. The high peaks of June 1 and 5 followed days or little or no draft on May 31 and June 4 which were evidently holidays. As indicated by the hydrograph of Figure 6 the net daily fluctuations of water level in well 4 generally range from about 0·5 to 0·8 foot. These fluctuations were induced largely by intermittent withdrawals of water from some 5 active irrigation wells located

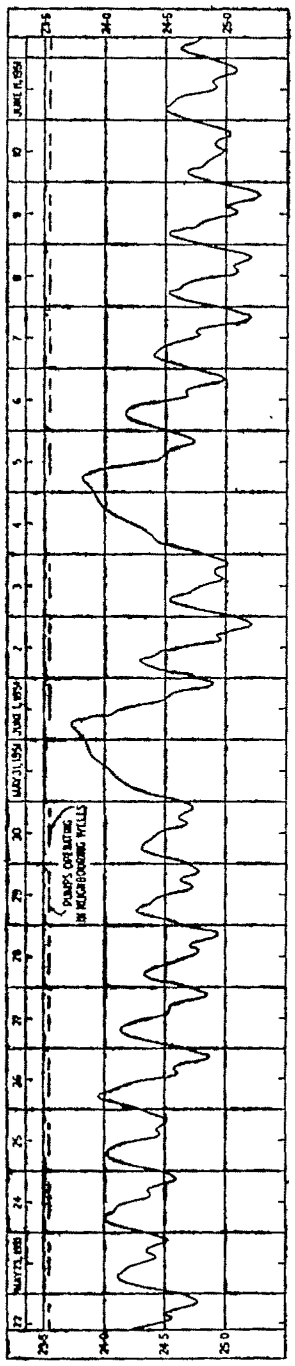


FIGURE 6. HYDROGRAPH OF WELL 4, KHEDOI IRRIGATED TRACT, SHOWING TYPICAL DAILY FLUCTUATIONS OF WATER LEVELS, MAY-JUNE 1951

within a 600-foot radius of well 4. The total draft from these wells was at an average rate of about 270,000 gallons per day during the period of observation.

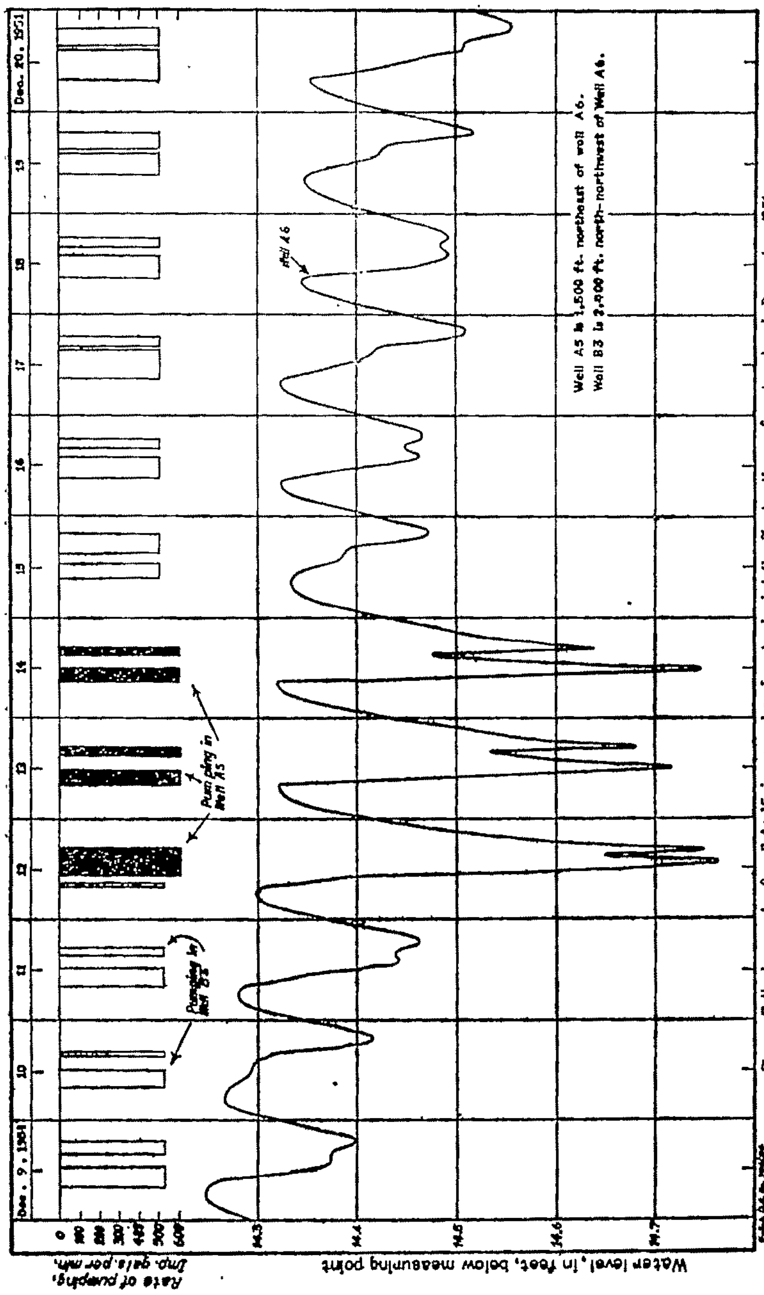


Figure 7. Hydrograph of well A_6, Viri area, showing typical daily fluctuations of water level, December 1951.

Figure 7 shows typical daily fluctuations of water level in observation tube well A_6 which is equipped with an automatic water-stage recorder. These fluctuations were induced by intermittent pumping in tube wells A_5 and B_3 for the Gandhidham-Kandla Port public supply. Well A_5 is located in the Viri area

1,500 feet northeast of observation well A_6. When pumping starts in either well A_5 or B_3, the static level in well A_6 begins to decline soon thereafter (Figure 7). On cessation of pumping the static level in well A_6 begins to rise almost immediately. Pumping in well A_5 has a considerably greater lowering effect on the static level of A_6 than pumping in Well B_3. For example, pumping from well A_5 at 600 Imperial gallons per minute for 3 hours in the morning of December 14, 1951 caused the water level in well A_6 to drop 0·43 foot. Pumping in well B_3 for 5¼ hours in the morning of December 16 at 500 gallons per minute resulted in a drop of only 0·15 foot in the water level of well A_6 (Figure 7). Because well A_5 is considerably nearer to well A_6 than well B_3, the lowering effect of pumping in well A_5 on the water level in well A_6 is correspondingly greater. The rapid transmission of the effects of pumping in wells A_5 and B_3 to well A_6 appears to indicate that the water in aquifers tapped by these wells is confined under artesian pressure and therefore that the fluctuations of water level in well A_6 represent changes in pressure head in these aquifers during pumping rather than changes in ground-water storage.

Withdrawals of water from wells for irrigation in the cultivated tracts as well as pumpage for the Gandhidham-Kandla Port public supply in the Viri area doubtless contribute substantially to the seasonal declines of the water table indicated by the hydrographs of Figures 2 and 4. However, these factors are combined with others such as evapotranspiration and spring discharge in producing the over-all seasonal lowering of water levels in wells.

Fluctuations related to changes in atmospheric pressure

Water levels in wells which tap water in confined or artesian aquifers commonly show fluctuations related to changes in atmospheric pressure. Such changes in pressure may cause the water level to fluctuate through periods of a few hours or days. As the atmospheric pressure increases the water level in the well tends to be depressed. Concurrently the increased atmospheric load is also imposed on the confining bed overlying the aquifer tapped by the well. However, the confining bed is competent in some degree to resist the increased load and transmits only a part of the air pressure change to the underlying confined aquifer. Consequently, the water level in the well is depressed by an amount equal to the proportion of the air pressure change that is not transmitted by the confining bed. The ratio of the water level change to the barometric change, in equivalent units is called the barometric efficiency of the well.

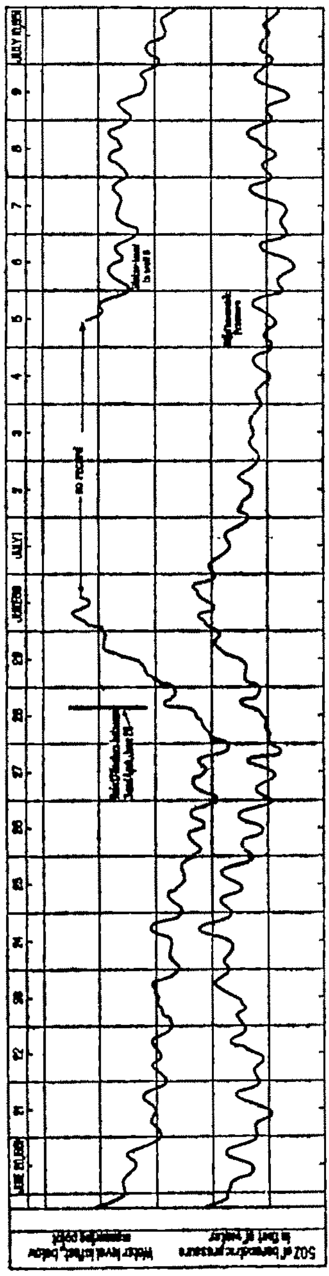


FIGURE 8 HYDROGRAPH OF WELL 6, NAGALPUR IRRIGATED TRACT SHOWING TYPICAL DAILY FLUCTUATIONS AND BAROGRAPH AT GANDHIDHAM, JUNE TO JULY 1959

In Figure 8 a hydrograph of well 6, in the Nagalpur irrigated tract is shown comparatively with the barogram registered by a recording microbarograph at Gandhidham. For better comparison, the barogram is plotted in inverted position because increases in barometric pressure tend to depress the water levels in wells. Moreover, the plotted barogram indicates only 50 per cent. of the actual barometric pressure inasmuch as the barometric efficiency of well 6 is approximately 50 per cent. As indicated in Figure 8 the hydrograph of well 6 commonly shows two peaks each day which correspond to diurnal lows in barometric pressure. The amplitude of the fluctuations in water level in well 6 induced by barometric changes ranges from about 0·02 to 0·05 foot a day. These fluctuations normally are superimposed on the seasonal or longer term trends of water levels. Thus as indicated in Figure 8 from June 19 to 27 the barometric fluctuations are superimposed on a generally declining water level at the end of the 1950-51 dry season and after June 28 on a rising water level following recharge from the first rain of the 1951 monsoon.

Water-level fluctuations resulting from barometric changes are no doubt fairly common in other wells of the Anjar-Khedoi region. However, these fluctuations which are of comparatively small magnitude are often masked by larger fluctuations caused by pumping. The tube wells of the Viri area might be expected to register barometric fluctuations if these were not masked by larger fluctuations due to pumping. During periods of cessation of pumping draft in the Khedoi irrigated tract, the water level of well 4 has shown twice daily lows and highs of about 0·02 to 0·05 foot amplitude that correspond to changes in atmospheric pressure. In the hydrograph of well 4 in Figure 6 the effects of barometric changes are indicated by the minor undulations on the rising (recovery) water level of May 31 and June 4. Wells located in or near areas where aquifers crop out at the surface or where the overlying confining bed is broken do not generally show barometric effects in their water-level fluctuations.

Source and replenishment of the ground water

The ultimate source of the water which sustains the groundwater body in the Upper Bhuj sandstones of the Kharma lowland and contiguous inliers of Viri and Mathada is rainfall. A part of the rain that falls returns to the atmosphere by evaporation, a part may run-off on the surface in streams but a considerable part seeps down to the water table to replenish the ground-water body.

Replenishment of the ground-water body takes place by direct infiltration from rain which falls on the land surface, by infiltration from ephemeral streams while in spate, by return seepage from irrigation, by ground-water inflow from areas outside the Anjar-Khedoi region and by underground leakage from Lower Bhuj into Upper Bhuj aquifers. Of these sources of recharge, direct penetration of rainfall is probably most important in the Anjar-Khedoi region. Practically all of the Khamra lowland as well as contiguous inliers near Viri and Mathada is underlain by permeable Upper Bhuj sandstones which are moderately absorptive to the deep penetration of percolating water. Moreover, the sandstones are commonly veneered with a mantle of loose sand or sandy soil that is even more absorptive than the underlying sediments. Thus the geologic conditions are favourable for recharge by direct rainfall penetration in most of the Khamra lowland and contiguous inliers, with the possible exception of areas of shallow water table or ground-water discharge.

Available data from the present investigation were not sufficiently precise to determine with exactitude the nature and amount of rainfall penetration. However, it is known that the rate and amount of infiltration generally depend on several variable factors among which are : (1) permeability of the soil, (2) nature of the plant cover on the soil, (3) conditions of soil moisture, (4) temperature and (5) duration, intensity and amount of precipitation during individual rain storms. The annual increments of recharge to the ground-water body also vary with the total annual rainfall. Replenishment is greatest in years with average or above average precipitation and is least in dry years. By analogy with conditions in comparable dry regions of western U.S.A., infiltration in the Anjar-Khedoi region might be expected to be of the order of about 25 per cent. of the rainfall of average years. However, in those years with annual rainfall less than half the average, the infiltration may be of the magnitude of about 5 per cent. or less. On the other hand as much as 40 per cent of the annual rainfall may penetrate to the ground-water body in exceptionally wet years.

The potential contribution of ground-water recharge by infiltration from ephemeral streams while in spate was not well demonstrated during the present study because little run-off occurred in streams of the Anjar-Khedoi region during the 1951 monsoon. Moreover, as discussed in the section of this report under "Drainage", run-off in significant quantity is **not likely** to occur except when the average rainfall during the southwest monsoon is about average (14 inches) or greater and when the rainfall during the span of a month is about 5 inches or greater. Thus run-off is likely to occur during one year out of about 2·4 years provided the rainfall during the span of a month is about 5 inches or greater. During the relatively abundant rains of the 1950 monsoon which caused a fairly high run-off in the Sang River, it is reported that in wells near that stream water levels rose several feet or more during the run-off period. Such rises can no doubt be attributed to infiltration from the Sang River itself. Infiltration from smaller streams crossing the Khamra lowland also occurs during run-off periods.

Most of the irrigated tracts of the Anjar-Khedoi region are underlain by relatively permeable sandy soils derived from Upper Bhuj sandstones. This condition facilitates the return seepage of a considerable part of the water withdrawn from ground water by irrigation wells. If the return seepage is taken as 20 per cent. of the water applied to the land for irrigation, then infiltration from this source may have been of the order of 2,500 acre-feet during 1951.

As suggested by the water-table contours of Plate 1 some ground water also moves into the Anjar-Khedoi region through Upper Bhuj aquifers from the area to the west of Loharia. In addition the water-table contours also suggest that leakage of ground-water from Lower Bhuj sediments into Upper Bhuj aquifers occurs along the margins of the Nigal upland and Samparda ridge (Plate 1).

Movement of the ground water

Ground water necessarily moves in the direction of the maximum hydraulic gradient, that is, at right angles to the contours of the water table as shown in Plates 1, 2 and 3. Moreover, the ground water is in constant motion from areas of intake or recharge toward areas of disposal or discharge. The rate of movement is proportional to the hydraulic gradient if the water-bearing material is homogenous. Although considerable differences may exist among the component members of the Upper Bhuj series, it is probable that the formation functions essentially as a single hydrologic unit. The water-table contours for May 1952 (Plate 1) indicate (1) that the movement of ground water was southeasterly with a gradient of about 30 feet to the mile from Loharia toward Khedoi Mota, (2) that a depression in the water table defined by the 245-foot contour was developed in the Khedoi irrigated tract as a result of withdrawals for irrigation and natural ground-water discharge near

Khedoi Nana, (3) that a narrow ground-water divide marked by the 255-foot contour lay between the Khedoi depression and a relatively open trough in the water table centering around the Khamra irrigated tract, (4) that there was a general easterly movement of ground water on an average gradient of about 17 feet to the mile from the eastern flanks of the Nigal upland toward areas of ground-water withdrawal in the Anjar and Nagalpur irrigated tracts, (5) that there was a general southeasterly movement from Samparda ridge towards the vicinity of Anjar, (6) that troughs in the water table were developed around the Bhadroi, Sidungra, Nagalpur and Anjar irrigated tracts owing to ground-water withdrawals for irrigation and (7) that there was a general percolation of ground water into the Viri area from the west and northwest and that this water was being discharged by springs, evapotranspiration in phreatophyte tracts and by withdrawals from wells for irrigation and public supplies.

The direction of movement of ground water through permeable Upper Bhuj sandstones in the Anjar-Khedoi region is in part controlled by the interrelations of geologic structure, stratigraphy and topography and in part by withdrawals from wells for irrigation in cultivated tracts. On the east and northeast flanks of the Nigal dome and the south flank of Samparda ridge the direction of ground-water movement is essentially parallel to the dip. On the other hand, from the southern and southeasterly flanks of the Nigal dome there is southeasterly percolation oblique by as much as 30 to 45 degrees to the dip of the water-bearing strata. Moreover, the gradual southward thickening and the relatively impervious character of the Deccan trap flows to the south of the Khamra lowland apparently tend to impede down-dip ground-water movement in Upper Bhuj aquifers and to deflect that movement along the strike. Thus south and southeast of Sidungra ground water moves eastward parallel to the strike passing through Upper Bhuj aquifers which are thinly covered by Deccan trap and discharges in the Viri inlier (Plate 1). Natural ground-water discharge takes place in or near the contact of the Deccan trap with Upper Bhuj sandstones where streams have cut topographic lows in this contact such as in Khedoi *Nala* at Khedoi Nana, in Viri *Nala* a tributary of Sang River just south and southeast of Viri and along Sang River one-half to three-quarters of a mile north and north-northwest of Viri. The Sidungra trap dyke, which extends east-west for some 5 miles from Sang River through Sidungra to a point near Pantia may also act as a partial but apparently not a complete barrier to north-south components of ground-water movement in the Khamra lowland. However, the water-table contours in Plate 1 suggest that general ground-water movement is sub-parallel to the trend of the dyke. As indicated by the water-table contours (Plate 1) near Khedoi, Khamra, Sidungra, Mota Nagalpur and Bhadroi local diversion of ground-water percolation from its natural direction of movement has resulted from withdrawals for irrigation in cultivated tracts near these villages. Troughs in the water table resulting from such withdrawals are particularly well developed between Sidungra and Mota Nagalpur, northeast of Bhadroi and near Khamra. In addition a pronounced depression (Plate 1) has been developed in the water table in the cultivated tract near Khedoi.

Discharge of the ground water

Ground-water discharge from Upper Bhuj aquifers takes place by evaporation and transpiration of ground-water plants, by the flow of springs and by withdrawals from wells for irrigation and public supplies. Evaporation and transpiration of ground water occur principally in those areas where the water table is less than 10 feet below the land surface. Shallow-water tracts of natural ground-water discharge formerly existed in Upper Bhuj inliers about 6 furlongs southwest and 2 furlongs north of Anjar as well as in the cultivated tract about one mile north of the city. However, the ground water that formerly escaped at the surface in these areas has now been diverted to nearly wells by withdrawals for irrigation. Existing areas (1952) of shallow water table and natural ground-water discharge now are found in a band along Khedoi *Nala* just southeast of Khedoi Nana, south and southeast of Viri and in a small inlier about a mile northeast of Viri (Plate 1). These areas support a vigorous growth of ground-water plants or phreatophytes which include palms, willows, salt grass, tamarisk, sedges and rushes. These plants evidently dissipate a considerable volume of ground water by transpiration, especially during wet years. Where the water table is at or near the surface or the capillary fringe extends to the surface there is also active ground-water discharge by evaporation. The amount of transpiration and evaporation varies considerably from day to day and from season to season depending on the rate of plant growth, temperature, relative humidity, wind movement and other factors. In the Anjar-Khedoi region ground-water discharge by evapotranspiration from Upper Bhuj aquifers was most active during 1951-52 in an area of about 30 acres near Khedoi

Nana, abount 68 acres south and southeast of Viri and 4 acres in the small inlier about one mile northeast of Viri. These areas are shown by shading in Plate 1. If the specific yield of the water-bearing materials in these areas is taken as 10 per cent., the depth of water withdrawn from ground water by plant transpiration and soil evaporation ranged from about ·011 to ·025 foot per day and averaged ·015 foot per day during June 1951. These figures were computed by White's formula (White, p. 61) from diurnal water-table fluctuations measured by automatic water-level recorders in a 6-foot pit about 1,300 feet south of Viri and in well 3 about 500 feet south of Viri. Inasmuch as the shallow-water tracts in the Upper Bhuj series of the Anjar-Khedoi region cover about 102 acres, the average ground-water discharge by evapotranspiration from these during June 1951 was of the order of 1·5 acre-feet per day or roughly 407,000 Imperial gallons per day.

A considerable volume of ground water is also discharged by numerous perennial seeps and springs which issue from Upper Bhuj aquifers along Khedoi *Nala* near Khedoi Nana, along Sang River about 6 furlongs north-northwest of Viri, and in tributaries of the Sang River about 2 furlongs southeast of Viri. During June 1951 the aggregate spring discharge near Khedoi Nana was about ¼ cubic foot per second, along the Sang River about ¾ cubic foot per second and in Viri springs about one cubic foot per second. This is equivalent to a total spring-fed discharge of roughly 2 cubic feet per second from Upper Bhuj aquifers in the Anjar-Khedoi region or about 4 acre feet per day.

As based on a detailed inventory of existing wells in the Anjar-Khedoi region, the total withdrawal of ground water for irrigation from some 10 cultivated tracts during 1951 was at an average rate of about 12,013,000 Imperial gallons per day (44·2 acre-feet per day) during an irrigation season lasting approximately 8 to 10 months per year. The total annual draft from wells for irrigation during 1951 was approximately 12,645 acre-feet in the Anjar-Khedoi region.

In 1951 the natural ground-water discharge by evapotranspiration and by spring flow was roughly 2,000 acre-feet and artificial discharge by withdrawals from wells amounted to about 12,645 acre-feet. Thus the combined natural and artificial discharge of ground-water from Upper Bhuj aquifers of the Anjar-Khedoi region by evaporation, transpiration, spring flow and withdrawals for irrigation was of the order of 14,645 acre-feet in 1951.

Present utilization of ground water from Upper Bhuj aquifers

As based on a detailed inventory during 1951-52 there were some 660 wells, either of dug or dug and bored construction in the Anjar-Khedoi region that tap water-bearing sandstones in the Upper Bhuj series at depths ranging from 15 to 247 feet below land surface. In addition there were 5 tube wells in the Viri area from 155 to 228 feet deep that are used for the Gandhidham-Kandla Port public water supply. Hydrologic data for the 5 Viri tube wells are given in Appendix 9 and Table 16 and for other wells in the region in Appendix 15.

TABLE 16

Hydrologic data for tube wells in the Viri area at the time of completion in 1951.

(From data supplied by John Mowlems Co., Ltd., drilling contractors.)

Well number	A_3	A_2	A_6	B_1	B_2
Date well completed (1951) . .	Mar. 9	Apr. 24	May 27	May 17	May 8
Completed depth of well (feet) . .	220	210	155	228	215
Diameter of upper blank casing (inches)	12	12	12	12	12
Setting of upper blank casing (feet below land surface).	0—68	0—68	0—68	0—68	0—68
Diameter of lower casing (inches) .	8	8	8	9	8
Setting of lower casing (feet below land surface).	60—220	60—210	59—155	60—68	80—215
Position of slotted section or screen (feet below land surface).	68—220 (Slots)	68—201 (Slots)	69—155 (Slots)	68—220 (Screen)	88—215 (Slots)
Date of pumping test (1951) . .	Mar. 9	Apr. 24	May 27	May 17	May 3
Duration of test (hours) . . .	16	24	24	24	24
Average rate of pumping (Imp. gals./min.).	683	683	417	683	467
Static water level (feet below land surface).	0	8	12½	12½	20
Maximum pumping water level (feet below land surface).	14	17	25	25¼	28
Maximum drawdown (feet) . .	14	9	12½	12¾	8
Specific capacity (Imp. gals./min./ft. of drawdown).	48·8	70·3	33·3	49·6	58.4

All of the 5 Viri tube wells were put down by percussion drilling machine with a 13-inch open hole from top to bottom. As shown in Table 16 the upper section of each tube well is lined with 12-inch blank steel casing. The lower section of each well, with the exception of well B_1, is provided with an 8-inch slotted casing and the annular space between the slotted 8-inch casing and the walls of the 13-inch hole is packed with crushed gravel of 3/16 to $\frac{3}{8}$-inch dimeter. The slots in the 8-inch casing are 6-inches long and 1/16-inch wide and are set 2-inches apart. The upper end of the 8-inch casing in each well is blank and is telescoped within the 12-inch casing with an overlap of 8 to 10 feet. The annular overlapped space between the casings is sealed by cement. Instead of gravel-packed slotted 8-inch casing, well B_1 is provided with a gravel-packed 9-inch, 17-gauge well screen (strainer) but in other respects the details of construction are similar to the other Viri tube wells. The yields, drawdowns, specific capacities and construction details of the Viri tube wells at the time of their completion in 1951 are given in Table 16. These data were supplied by John Mowlems Co., Ltd., drilling contractors.

As of May 1954 three of the Viri tube wells were equipped with deep well turbine pumps, one was pumped intermittently by air lift and one was used as an observation well. Currently (May 1954) tube wells A_5, B_1 and B_3 are being pumped alternately in pairs at 8 to 9 hours per day each for the Gandhidham-Kandla Port water supply. From late 1951 when the wells were first put into operation up to May 1954 the pumpage from the Viri tube wells ranged from 99,000 to 558,000 gallons per day. During May 1954 pumpage ranged from 504,000 to 700,000 gallons per day with an average of 582,000 gallons per day. (See Appendix 14.) The yields, static water levels, pumping water levels, drawdowns and specific capacities of tube wells A_5, B_1 and B_3 during May 1954 are given below in Table 17:

TABLE 17

Hydrologic data for operating tube wells in the Viri area as of May 1954.

Well No.	A_6	B_1	B_3
Approximate mean static level (feet below measuring point) at start of day's pumping.	16	22	28
Approximate mean pumping level (feet below measuring point) at end of day's pumping	41	39	62
Approximate mean drawdown (feet) . .	25	17	34
Rate of pumping (Imp. gallons per minute) .	590	590	590
Specific capacity (Imp. gallons/minute/foot of drawdown).	23·6	34·7	17·3

With the exception of the tube wells in the Viri area all of the 660 wells inventoried during 1951-52 in the Anjar-Khedoi were of open, dug construction and of relatively large diameter. The depths of the existing dug wells in Upper Bhuj sandstones range from 15 to 90 feet and most of these extend from 5 to 15 feet below the low stage of the water table. Many dug wells of the region that are used for irrigation have been deepened by boring in order to increase yields by tapping deeper aquifers. In common practice one or more holes of 4 to 6-inch diameter are put down in an existing dug well by hand-boring machine. Such borings are in most instances left uncased and hence eventually cave in or clog and lose their effectiveness. However, in some instances a few feet of casing are placed in the upper part of the boring to give it a somewhat longer life. At the time of the inventory the greatest depth reached by hand boring was 247 feet in well 443 which was first dug to a depth of 67 feet and then deepened by two open borings of 150 and 180 feet.

During the past decade (1944-54) mechanical pumps have been used to an increasing degree in the Anjar-Khedoi region as well as in the rest of Kutch owing to increased efficiency and economy of pump operation over to the age-old method of drawing water from wells by bullocks and mote (leather bag). With the exception of 3 deep-well turbine pumps in use in the Viri tube wells, all mechanical pumps in operation during 1951-52 in the region were single-stage, 2 to 4-inch, horizontal cetrifugal pumps belt-driven by small Diesel motors. The number and yields of mechanical pumps in the several irrigated tracts of the Anjar-Khedoi region are given below in Table 18:

TABLE 18

Name of irrigated tract	No. of mechanical pumps	Maximum rate of pumping (Imp. gal./min.)	Minimum rate of pumping (Imp. gal./min.)	Median rate of pumping. (Imp. gal./min).
Loharia-Khirasra	0	..	..	..
Khedoi	25	380	60	170
Mathada	0	..	..	..
Pantia	2	110	50	..
Khamra	7	200	60	150
Samparda-Bhadroi	0	..	..	..
Sidungra	3	120	80	80
Nagalpur	27	300	58	140
Viri	1	..	..	120
Anjar	13	170	50	130

As indicated in Table 18 there were some 78 horizontal centrifugal pumps in operation on irrigation wells of the Anjar-Khedoi region. The yields obtained from pumps on these wells range from 50 to 380 Imp. gallons per minute. The most heavily pumped irrigation well of the region is evidently well 177 (Appendix 15) in the Khedoi irrigated tract. This well is normally pumped at 380 gallons per minute for 8 hours a day during a 10-month irrigation season—equivalent to a daily draft of about 180,000 gallons. The daily draft from wells equipped with pumps of median yield (140-150 gallons per minute) is about 67,000 to 72,000 gallons for a 8-hour operating day.

In spite of the increasing use of mechanical pumps in the region, most of the water for irrigation and to less extent for domestic and live-stock purposes is still drawn (1954) from wells by the "mote" (leather bag) each motivated by a yoke of bullocks. The present draft from individual wells by this means ranges from about 8,000 to 36,000 gallons a day with one to 3 motes working simultaneously in the same well for a 8-hour working day. Potentially, however, many individual dug wells of the Anjar-Khedoi region are capable of yielding as much as 100,000 (one lakh) gallons per day when fitted with mechanical pumps.

The principal crops irrigated from wells are wheat, millet and lucerne and to less extent garden vegetables and fruits such as papaya, guavas, mangoes and bananas. During 1951 there were 3,361 acres in the Anjar-Khedoi region that were being permanently or intermittently irrigated from wells in the Upper Bhuj series during an irrigation season which lasts from about 8 to 10 months a year. This acreage was covered by some 533 active wells of which 78 wells were equipped with mechanical pumps and 455 wells from which water for irrigation was drawn by motes and bullocks. At the time of the well inventory in 1951 the total draft for irrigation was at an average rate of about 12,645 acre-feet per year or an average of about 44·2 acre-feet per day during the irrigation season. The acreage irrigated, the number of active wells, the annual draft from wells and the average yearly water use per acre in the several irrigated tracts of the Anjar-Khedoi region are given in Table 19 below:

TABLE 19

Name of irrigated tract	Area irrigated by wells (acres)	No. of active wells in tract	Annual draft (1951) from wells (acre-feet)	Average annual water use per acre (acre-feet).
Loharia-Khirasra	109	17	208	1·9
Khedoi	901	136	3,937	4·4
Mathada	65	13	167	2·6
Pantia	123	21	308	2·5
Khamra	208	32	924	4·4
Samparda-Bhadroi	371	52	387	1·0
Sidungra	211	31	630	2·9
Nagalpur	514	83	2,867	5·7
Viri	133	35	535	4·0
Anjar	726	113	2,582	3·5
TOTAL	3,316	533	12,645	3·1

The approximate daily draft, in Imperial gallons, from each of the irrigated tracts of the Anjar-Khedoi region during the 6 to 10-month irrigation season of 1951 is given below in Table 20:

TABLE 20

Name of irrigated tract	Approximate daily draft (1951) (Imperial gallons)
Loharia-Khirasra	230,000
Khedoi	3,860,000
Mathada	166,000
Pantia	286,000
Khamra	863,000
Samparda-Bhadroi	366,000
Sidungra	636,000
Nagalpur	2,881,000
Viri	400,000
Anjar	2,325,000
TOTAL	12,013,000

The data of Table 19 and 20 give a comparative picture of ground-water withdrawals and the intensity of water use and cultivation among the several irrigated tracts of the Anjar-Khedoi region in 1951. Thus ground-water withdrawals were greatest in the Khedoi tract but the intensity of cultivation was greatest in the Nagalpur tract as reflected in the highest annual water use per acre in the region. The Nagalpur irrigated tract is devoted principally to fruit and garden crops which have a relatively high water requirement and which are more or less permanently irrigated. The Khedoi, Khamra, Viri and Anjar tracts are in part in cereal crops and in part in fruit and garden crops so that the over-all annual water use per acre is somewhat lower than in the Nagalpur tract. Tracts of lower water use such as Loharia-Khirasra and Samparda-Bhadroi are mainly devoted to the cultivation of cereals whose water requirement is relatively low and whose irrigation is intermittent.

Perennial yield from Upper Bhuj aquifers

The perennial yield of the Upper Bhuj sandstones in the Anjar-Khedoi region is the average quantity of ground water that is available for withdrawal year after year. This quantity is essentially equivalent to the long-term average recharge to Upper Bhuj aquifers plus the salvagable discharge. In wet years recharge is relatively high and probably exceeds the current rate (1951-54) of withdrawal from the ground-water body. The excess is carried over into dry years when recharge is considerably less than withdrawals.

Basic data from the present investigation were not sufficient to make firm estimates of recharge. However, rough calculations based on available data indicate that the annual recharge from all sources to Upper Bhuj aquifers within the region may range in magnitude from about 3,000 acre-feet in dry years to as much as 18,000 acre-feet in wet years. In addition ground water is transmitted into the region through Upper Bhuj aquifers from the area to the west of Loharia (Plate 1). Ground water also enters Upper Bhuj aquifers by underground leakage from Lower Bhuj sediments especially around the margins of Lower Bhuj outcrop areas (Plate 1).

The total withdrawal from wells in Upper Bhuj aquifers of the Anjar-Khedoi region was approximately 12,645 acre-feet in 1951, a dry year in which the artificial draft was probably somewhat greater than average. During the same year the natural ground-water discharge by evapotranspiration and spring flow was at a rate of about 2,000 acre-feet a year in areas near Khedoi Nana and Viri—equivalent to an average of about 5·4 acre-feet per day or roughly 1,465,000 imperial gallons a day. Of this quantity perhaps 50 per cent. or about 700,000 gallons (7 lakhs) per day could be considered salvagable in 1951 through additional withdrawals from wells in or near areas of natural discharge. Since late 1951 the Viri tube wells have been in operation and currently (May 1954) the draft from these is 500,000 to 700,000 gallons per day. Consequently salvagable natural discharge in the Viri area is probably now essentially diverted or in the process of diversion to the tube wells. The salvagable discharge near Khedoi Nana is considerably less than that in the Viri area. Ultimately it is to be expected that this water will also be diverted to the irrigation wells of the Khedoi tract through increasing draft by mechanical pumps.

The safe yield of the ground-water body in Upper Bhuj sandstones of the Anjar-Khedoi region is equivalent to the long-term average recharge plus the salvagable natural discharge. There is no rejected recharge from Upper Bhuj aquifers of the region that can be diverted underground by pumping. Moreover, the salvagable natural discharge in the Viri area, which was available in 1951, is now (1954) essentially appropriated by the Viri tube wells and a small natural discharge in the Khedoi Nana area is currently in the process of diversion to the Khedoi irrigated tract by the increasing draft of mechanical pumps. Thus on the basis of incomplete data the long-term safe yield is estimated to be of the order of 10,000 to 12,000 acre-feet per year. The current (1951-54) rate of withdrawal from existing, irrigation wells of the region and from the Viri tube wells is roughly equivalent to and even slightly exceeds the estimated safe yield. Therefore any additional draft on the ground-water body would necessarily be taken from storage and could not be indefinitely sustained without detriment to existing wells.

WATER IN LOWER BHUJ AQUIFERS

Occurrence of the ground water

Sufficient data were not available from the present investigation to show the form and slope of the water table in Lower Bhuj aquifers by contours. However, available data suggest that the water table in the Nigal dome slopes centrifugally southeast, east and north toward the Khamra lowland in approximate conformity to the dip of Lower Bhuj strata in the Nigal dome. The water table in Lower Bhuj aquifers of Samparda ridge apparently slopes south and southeast toward the Khamra lowland.

In the Nigal upland the water table in Lower Bhuj aquifers crops out in springs near Wada and lies at or near the surface in the phreatophyte tract just south of the village (Plate 1). The greatest measured depth to water was 85·87 feet at well 776 which lies in the Ratnal irrigated tract about one mile north-northeast of Nigal. The ranges in and the median depths to water in three irrigated tracts where wells tap water in Lower Bhuj aquifers is given in Table 21. These data are based on water-level measurements made in early 1952.

TABLE 21

Name of irrigated tract	No. of wells observed	Range in depth to water (feet below land surface)	Median depth to water (feet below land surface)
Ratnal	86	42—86	65
Wada	5	15—26	22
Nigal-Malinga	13	30—60	36

No continuous observations of water levels were made in wells tapping water in Lower Bhuj aquifers during the present investigation. Hence, the causes and nature of the fluctuations of ground-water level cannot be discussed in detail. In all likelihood, most types of water-level fluctuations which have been distinguished in wells tapping Upper Bhuj aquifers may also occur in wells in the Lower Bhuj.

The principal source of replenishment of ground water in Lower Bhuj aquifers is infiltration from rain which falls on outcrop areas in the Nigal upland, Samparda ridge and the northwest salient of the Khamra lowland. Additional recharge is also provided by infiltration from ephemeral streams while in spate, particularly from the Sang River where it crosses outcrop areas of Lower Bhuj strata. The amount of replenishment varies greatly from year to year depending principally on the quantity of annual rainfall as well as other variables which have been previously discussed. Owing to intercalations of relatively impervious shales, siltstones and fine compact sandstones with permeable Lower Bhuj sandstone aquifers, the quantity of infiltration from rain and streams is probably considerably less than that in Upper Bhuj strata in which permeable sandstones predominate.

Ground water in Lower Bhuj aquifers moves down the slope of the water table toward areas of natural and artificial discharge. The ground-water body of the Nigal upland discharges naturally by evapotranspiration and spring flow near Wada and probably by underground leakage into Upper Bhuj aquifers of the Khamra lowland. Artificial discharge from Lower Bhuj aquifers takes place by withdrawals from wells for irrigation in the Ratnal, Wada and Nigal-Malinga cultivated tracts. Probably most of the water which enters Lower Bhuj aquifers of Samparda ridge eventually discharges by underground leakage into Upper Bhuj aquifers of the Khamra lowland.

Present utilization of ground water from Lower Bhuj aquifers

During the present investigation some 106 wells which tap water in Lower Bhuj aquifers were examined. This number includes a complete inventory of the wells in the Ratnal irrigated tract but wells in the Wada and Nigal-Malinga tracts were only partly inventoried. The wells examined range from 24 to 185 feet deep. They are all of open construction and are generally dug from about 5 to 15 feet below the low stage of the water table. In order to increase yields many of the dug wells have been deepend by 4 to 6-inch borings put down by hand-operated auger tools. Some of the borings are partly cased. However, many are simply open holes which eventually tend to cave in or clog after a few years service and thereby lose their effectiveness.

No mechanical pumps are currently (May 1954) in operation in any of the wells of the three irrigated tracts where Lower Bhuj aquifers are developed. Withdrawals of water from wells for irrigation are entirely by the bullocks and mote (leather bag) system. In the Wada and Nigal-Malinga irrigated tracts the daily draft from individual wells ranges from about 8,000 to 24,000 gallons using from one to 3 motes operating simultaneously in the same well for a 8-hour working day. Owing to relatively high lifts in the Ratnal irrigated tract, the daily draft from individual wells under the same operating conditions was about 4,000 to 15,000 gallons. With mechanical pumps it is probable that many of the existing wells are individually capable of yielding as much as 100,000 (one lakh) gallons a day.

At the time of the well inventory in 1952 there were 86 active wells in the Ratnal tract that were being used to irrigate some 644 acres with an estimated total withdrawal from the wells of 839 acre-feet per year. Thus on the average one well covered about 7·4 acres with an average yearly water use of about 1·9 acre-feet per acre. In the Wada and the Nigal-Malinga tracts there were some 15 and 36 active wells used to irrigate scattered small cultivated plots. The area covered per well and the average yearly water use per acre were about the same as in the Ratnal tract. The principal cultivated crops in these three irrigated tracts were wheat and millet. Inasmuch as these require only intermittent irrigation the average water use per acre was less than other more intensively cultivated tracts of the region such as Nagalpur, Khedoi and Khamra (Table 19).

CHEMICAL QUALITY OF THE GROUND WATER

General Features

The chemical quality of a water is a factor of paramount importance in its utilization for irrigation, public supplies and domestic purposes. During the present investigation numerous analyses of waters from wells of the region were made in the course of studies of chemical quality. Most of the analyses were made in the chemical laboratory of the Sindhu Resettlement.

Corporation (S.R.C.) in Gandhidham, many were made in the Imperial Chemical Industries Laboratory in Ahmedabad and still others, in the Geological Survey of India (G.S.I.) laboratory in Calcutta.

For construction of the chloride maps of Plates 4 and 8 water samples were taken from 416 wells of the Anjar-Khedoi region and analyzed for chlorides in the S.R.C. laboratory. These data are given in Appendix 1. Complete chemical analyses (Appendix 2) of water samples from 9 shallow wells of the region and partial analyses (Appendix 3) of water samples from 7 other wells were made in the G.S.I. laboratory. Other partial chemical analyses of the S.R.C. laboratory for water samples from 14 shallow wells in the Viri area are given in Appendix 4. Partial chemical analyses of water samples taken from various depths in 8 exploratory borings in the Anjar-Khedoi region are given in Appendix 5. Water samples taken intermittently from the 5 production tube wells of the Viri area during February 1951 to May 1954 were partially analyzed in the S.R.C. laboratory and these data are given in Appendix 6. As a check on possible brackish water encroachment all 5 of the Viri tube wells have been examined periodically from February 1951 up through May 1954 for chloride content. These analyses made in the S.R.C. laboratory are given in Appendix 7.

Among the 31 waters whose analyses are given in Appendices 2-4, there are apparently some 13 which are mainly sodium chloride type waters, 7 which are waters of sodium bicarbonate type and 11 which are of mixed sodium chloride, sulphate and bicarbonate type. Sodium rather than calcium or magnesium appears to be the chief basic constituent of the waters, although data in this regard are not complete. Chloride is the main acid constituent in 16 of the waters, bicarbonate in 15 and sulphate in none. All of the waters sampled are moderately to highly mineralized as is generally characteristic of ground water in the arid and semi-arid regions of the world.

Quality character with respect to use for irrigation and public supplies

Although the chemical quality of a water is of first importance in its successful use for irrigation, other factors such as character of the soil, the amount of water used, rainfall and drainage must also be considered. A publication by Scofield (1933, pp. 21-24) has suggested certain limits for the characteristics of irrigation water as shown in Table 22 below:

TABLE 22

Constituents	Lower	Intermediate	Upper
	(Parts per million)		
Total dissolved solids . . .	0—700	700—2,000	2,000+
Sulphate (SO_4)	0—192	192— 480	480+
Chloride (Cl)	0—142	142— 355	355

In general, waters with qualities lying within the lower set of limits are not likely to be harmful when used in ordinary irrigation. Waters in the intermediate range may or may not cause injury to soil or crops depending on the relative concentrations of various constituents in the water, the nature of the soil and the way the water is used. Waters whose concentrations exceed the upper limits shown in Table 22 are very likely to be unfit for irrigation because of their toxic effects on the soil or on the plants. The suitability for irrigation of shallow ground waters in the Manchhar series, in the Deccan trap, and in the Lower and Upper Bhuj series is shown in Table 23:

TABLE 23

(Number of samples from each source that fall into the classification of Table 22)

Geologic unit	Category	Total dissolved solids.	Sulphate (SO_4)	Chloride (Cl)
Manchhar series (5 samples)	Lower . .	0	1	0
	Intermediate .	0	4	0
	Upper . .	5	0	5
Deccan trap (5 samples)	Lower . .	0	5	1
	Intermediate .	3	0	0
	Upper .. .	2	0	4
Upper Bhuj series (18 samples).	Lower . .	7	16	7
	Intermediate .	9	2	7
	Upper . .	2	0	4
Lower Bhuj series (3 samples).	Lower . .	1	1	0
	Intermediate .	0	1	1
	Upper .	2	1	2

As suggested by Table 23 the water in the Manchhar series is generally less suitable for irrigation than that of the Deccan trap or the Bhuj series. Moreover, water in the Upper Bhuj series generally appears to be of better quality than that in the other formations of the region. In all the formations the sulphate content seldom exceeds the upper safe limits of Table 22. Evidently high chloride and total solids are the most frequent causes in the water for toxicity to soils and plants. In spite of the adverse indications of Table 22 many waters belonging to the intermediate and upper categories are successfully used in the Anjar-Khedoi region where good subsoil drainage prevails and salt resistant crops are cultivated. Moreover, the rains of the southwest monsoon are generally adequate to flush out salts accumulated in the soil from successive irrigations of the dry season.

In the utilization of a water for public and domestic supplies the chemical quality is also a first consideration. Attractive taste and lack of colour or odour are the principal requisites of such a water. The waters from most wells in the Anjar-Khedoi region are colourless but in some cases waters with a high iron content assume a slightly yellowish colour. Odours are generally absent in the waters from most wells of the region except where these have been allowed to become foul with decaying plant matter and animal droppings. Except in instances where wells have been polluted by organic matter, the taste of a water generally depends on the chemical character and amount of dissolved constituents.

The quality of a water that may be considered satisfactory for drinking and domestic purposes varies considerably and depends on the locality and the individual. In U.S.A. the Public Health Service has set up certain standards as desirable in water for domestic purposes. The upper limits suggested are not rigid but are considered desirable. In common experience many waters exceeding the indicated limits in some respects have been used for long periods—apparently without harmful effects. The limits suggested by the Public Health Service are given below in Table 24:

TABLE 24

	(Parts per million)
Total solids	1,000
Iron (Fe)	0·3
Magnesium (Mg)	100
Sulphate (SO_4)	250
Chloride (Cl)	250

Of 31 waters in the Anjar-Khedoi region whose analyses are given in Appendices 2-4, only 5 are within the limits set in Table 24 but many others whose constituents exceed the prescribed limits are used and no harmful results have been noted. In addition, the characteristic of hardness of water is important in its use for domestic and industrial purposes. Hardness is caused largely by dissolved calcium and magnesium and is reported as the amount of calcium carbonate equivalent to all the calcium, magnesium and other constituents that cause hardness. This characteristic of a water is indicated by the amount of soap required to produce lather and by the amounts of deposits of insoluble salts formed from the water in pipes and boilers as a result of heating or of changing pressure. Waters with less than 50 parts per million of total hardness are generally considered to be soft, waters between 50 and 150 parts are of intermediate hardness and greater than 150 parts they are hard. Thus among 24 analyses in Appendices 2 and 4, none of the waters can be classified as soft but some 3 are of intermediate hardness and 21 are moderately to very hard.

Distribution of salinity in the shallow ground water of the Bhuj series

The chloride ion is generally a rather good index of water salinity and is moreover, relatively easy to determine analytically. During the course of the present investigation analyses for chloride were made of water samples from some 416 shallow wells (Appendix 1) in the Anjar-Khedoi region. These data were used to construct Plates 4 and 8 which show areally the distribution of the chloride ion in the shallow ground water of the Upper and Lower Bhuj series. The ionic concentration of dissolved salts in the ground water may vary considerably from year to year and from season to season. Thus the pattern of salinity distribution shown in Plate 4 (February—May 1952) and Plate 8 (June 1951) while valid for the periods of observation may be appreciably different in other years or seasons. Periodic sampling from season to season and from year to year is required to ascertain the magnitude of these changes.

As shown in Plate 4 the shallow ground water of the Upper Bhuj series generally contains less than 250 parts per million of chlorides in most areas where there is little or no use of the ground water for irrigation. On the other hand there is a notable increase in chlorides in and near the irrigated tracts as (for example near Khedoi, Pantia, Khamra, Sidungra, Nagalpur, Viri and Anjar). In a small area about one-half mile east of

Khedoi Mota the chloride concentration exceeds 2,500 parts per million, in an area about one mile southwest of Kharma it is greater than 1,750 ppm and near Sidungra and Nagalpur it is more than 1,000 ppm. A broad belt of high chlorides also stretches from north of Anjar to the vicinity of Viri (Plate 4).

Sufficient data were not available to show adequately the distribution of chlorides in the shallow ground water of the Lower Bhuj series. However, as indicated in Plate 4 the chloride concentration exceeds 1,500 parts per million in two parts of the Ratnal irrigated tract and in part of the Nigal-Malinga tract it is greater than 1,000 ppm.

The high salinity of the shallow ground water in and near the cultivated tracts results principally from the down leaching of salts accumulated in the soil by the return seepage of irrigation and perhaps also by infiltrating rain water. Salts tend to accumulate in the soil by evaporation of the nominally mineralized water used for irrigation and as a consequence of repeated irrigations with such water. As a net result the salinity of the shallow ground water in and adjacent to the irrigated tracts reaches a much higher concentration than that in areas where ground water is not developed for irrigation.

Ground-water discharge by evapotranspiration also tends to accumulate salinity in the ground-water body of discharge areas. Thus, the belt of high chlorides extending from north of Anjar to the vicinity of Viri (Plate 4) probably corresponds to a zone of natural ground-water discharge that formerly existed along most of this stretch. Similarly the belt of high chlorides along the south side of the Khedoi irrigated tract corresponds to a zone in which there was formerly natural ground-water discharge. Moreover, the ground-water salinity in this zone has been further increased by irrigation.

Salinity in deep aquifers of the Bhuj series

Sampling of waters from deeper aquifers of the Bhuj series during the exploratory drilling operations has shown that appreciable differences in salinity exist between the shallow ground water developed by most wells of the region and the water of the deeper aquifers. These data are given comparatively in Appendix 5. Most of the exploratory borings show a progressive increase in salinity in successively deeper aquifers—both in total dissolved solids in the water as well as in almost all dissolved constituents. Thus in exploratory boring A, in the Viri area the total solids increase from 918 parts per million at a depth of 75 feet to 3,246 ppm, at 540 feet. In exploratory boring KH_1 near Khamra the total solids increase from 282 ppm in the water between land surface and 100 feet to 2,457 ppm in the depth range, 315-700 feet. Similar conditions prevail at exploratory boring BH_1 and N_2. However, in exploratory boring K_2 near Khedoi Mota the total solids of a sample taken from 75 feet were 1,722 ppm but with depth salinity decreased so that in the depth range, 337-700 feet, the total solids were only 680 ppm.

The higher salinity which generally characterizes the water of the deeper aquifers of the Bhuj series can possibly be attributed to a more circuitous route and a slower rate of groundwater circulation than prevails in the shallow aquifers. Thus there is generally a greater opportunity for the water of deep aquifers to pick up dissolved mineral matter from the rocks than there is for the shallow ground water whose path of circulation is relatively short.

Seasonal changes in ground water salinity

Sufficient data were not available from the present investigation to determine the nature of seasonal and yearly changes in ground water salinity for most of the Anjar-Khedoi region. However, data obtained by the S.R.C. laboratory for the 5 tube wells tapping Upper Bhuj aquifers in the Viri area give some idea of the magnitude of seasonal and annual changes in salinity. Samples for chloride analysis were taken at fairly frequent intervals and partial analyses of water samples from these wells were made at more irregular and infrequent intervals during the period February 1951 to May 1954. These data are given in Appendices 6 and 7. The data on the chloride analyses (Appendix 7) are summarized below in Table 25 :

TABLE 25

Well No.	No. of analyses (February 1951-May 1954)	Maximum chloride content (ppm)	Minimum chloride content (ppm)	Median chloride content (ppm)
A_3	29	300	240	278
A_5	31	270	211	238
A_6	9	72	59	61
B_1	46	193	155	182
B_3	40	94	77	87

It is noted that well A_3 has shown the greatest range of fluctuation in chloride content (60 ppm) during the period of observation and well A_4, the least (13 ppm). The average range of fluctuation in chloride content for all 5 wells has been about 35 ppm during the period February 1951 to May 1954. Data on total dissolved solids and total hardness as $CaCO_3$ given in detail in Appendix 6 are summarized in Table 26 below:

TABLE 26

Well No.	No. of analyses (Feb. 1951-May 1954)	Max. total solids (ppm)	Min. total solids (ppm)	Median total solids (ppm)	Max. hardness (ppm)	Min. hardness (ppm)	Median hardness (ppm)
A_5	8	975	838	904	392	125	265
B_1	22	780	626	742	284	210	250
B_3	25	521	450	466	240	150	207

Among the 3 wells listed in Table 26 the average range in fluctuation in total dissolved solids has been about 120 ppm during the period of observation and the average range in fluctuation in total hardness as $CaCO_3$ has been about 143 ppm.

The available salinity data of Appendices 6 and 7 is not sufficiently continuous to be susceptible of direct correlation with seasonal and annual changes affecting the ground-water body in the Upper Bhuj series of the Viri area. However, in a rough sense, it appears that the salinity is generally highest near the end of the dry season and is lowest during or shortly following the period of monsoon recharge. Elsewhere in the Anjar-Kheodi region, cultivators report that perceptible increases in the salinity of the shallow ground water occur in the irrigated tracts during dry cycles of two more years. This observation appears to be reasonable but has not been verified by chemical analysis.

EXPLORATORY DRILLING FOR WATER IN THE ANJAR-KHEDOI REGION

At the instance of the Kandla Port Authority, 8 deep exploratory borings were put down in the Anjar-Khedoi region as a part of the ground-water exploration and development programme for the Kandla Port water supply. The boring operations were carried out by John Mowlems Co., Ltd., drilling contractors under the immediate supervision of Mr. G. E. N. States, who also directed the sampling and testing work. Drilling operations on the exploratory borings started in June 1950 and continued intermittently in the Anjar-Khedoi region until January 1952.

The principal objectives of the exploratory programme were (1) to determine the hydrostatic heads, depth, thickness and lithologic character of the water-bearing sandstones in the Bhuj series down to a maximum depth of 850 feet, (2) to test the chemical quality of the water in the sandstone aquifers and (3) to test the water-yielding capacity of sandstone aquifers at different depths by rough pumping tests. The descriptions of locations and depths of the exploratory borings are given below in Table 27:

TABLE 27

Boring No.	Location	Depth (feet)	REMARKS
A_2	3 furlongs SE of Viri and 975 feet SE of tube well A_3.	206	Destroyed.
A_3	1½ furlongs S of Viri	850	Finished as tube well A_3 (depth 220 ft.)
AA_5	One-quarter mile SW of Viri	195	Destroyed.
BH_1	1⅝ miles SE of Bhadroi	700	Destroyed.
K_2	One furlong NNW of Khedoi Mota	705	Destroyed.
KH_1	5 furlongs E of Khamra	700	Destroyed.
N_1	5 furlongs E of Nagalpur and 30 feet E of N_2.	300	Destroyed.
N_2	5 furlongs E of Nagalpur	700	Destroyed.

The exploratory borings BH_1, K_2, KH_1 and N_2 were put down with a truck-mounted conventional rotary drilling rig manufactured by the George E. Failing Supply Co. of Enid, Okla, U.S.A. The essential parts of this rig are drilling rods, rotary table, circulating mud pump, power driven hoisting drum and a 28½-foot folding mast. The rotary table, mud pump and hoisting drum are driven by a 4-cylinder petrol engine mounted directly behind the truck cab. The drill rods are 2½ inches in outside diameter and in most of the drilling fishtail bits with two jet openings were used, screwed to the lowest member of the drill stem. The rig is designed for drilling small diameter holes to a maximum depth of 1,000 feet.

Rotary drilling is accomplished by rotating in the hole a drill stem to the bottom end of which is attached a bit or cutting tool that grinds or breaks up the material at the bottom of the hole.

This material is carried away by the drilling mud, which is pumped from a slush pit at the surface down through the drill stem to the bottom of the boring, passes out through openings in the bit and thence upward through the space between the drill pipe and the walls of the hole to the surface. Here, the material passes through a ditch, in which the sand and other coarse particles removed from the boring settle out, and thence to a slush pit for recirculating. Except for a section that extends a short distance below the surface, no casing is used in the hole during operations and drilling mud is depended upon to keep the walls of the boring from caving.

The exploratory borings A_2, AA_5 and N_1 were put down by a percussion drilling rig which was also used in drilling the upper 500 feet of exploratory boring A_3. Moreover, production tube wells A_5, A_4, B_1 and B_3 in the Viri area were also put down by the same type of rig. The percussion drilling machine used was a conventional truck-mounted type with a two-line hoist, one for operating the drilling tools and the other for operating the bailer or sand pump, a wire-line spudder for raising and dropping the tools ; a petrol engine for power and a folding mast. The machine is capable of drilling a 6-inch hole to a depth of about 1,000 feet or a hole of larger diameter to shallower depth.

Drilling by the percussion method breaks up the rock or loosens the material in the bottom of the boring by means of the impact of a heavy bit and drill stem lifted and dropped at regular intervals. The loosened material known as drill cuttings is removed from the hole by a bailer or sand bucket. In drilling a dry hole, water must be added to replace that taken out in removing the drill cuttings. In hard rock the hole is usually drilled without a casing but in soft caving or unconsolidated materials casing is required to keep the hole open. The casing is driven down by hammering action of drive clamps attached to the drill stem.

In the original plans for the Kandla Port exploratory drilling programme it was decided that the borings put down by the rotary method would be cored in order to obtain representative and uncontaminated samples of the various formations penetrated. Accordingly exploratory borings BH_1, K_2, KH_1 and N_2 were cored where feasible by coventional coring tool with a non-rotating inner barrel. The cores of 2-inch diameter were packed in shallow hinge-top boxes 5 feet long and 6 inches wide. The coring operations were only partly successful. In practice it was found that the compact sandstones, shales and siltstones of the Bhuj series cored fairly well but the intercalated water-bearing sandstones which make up most of the series were too soft and friable to form satisfactory cores. In the borings put down by the percussion method samples were collected from drill cuttings brought up by bailer. Wash samples were also collected from the drilling mud when the core holes of exploratory borings BH_1, K_2 KH_1 and N_2 were reamed for water sampling and capacity tests. The cores and wash samples from the rotary drill borings and the samples of drill cuttings from the percussion drill borings were examined in detail by the writers and were used in preparing the lithologic logs of the exploratory borings given in Appendix 8 and of the Viri production tube wells in Appendix 9.

Mechanical analyses of representative formational samples were made in the Soils Laboratory of the Kandla Port Authority at Kandla. A set of 4 seives was used with openings of 0·06, 0·20, 0·60 and 2·00 millimeters and these were shaken by hand. The parts of the material retained on each screen and that passing all the screens were weighed separately and calculated as percentages of the total sample. For exploratory borings A_2, A_3, AA_5 and N_1 and production tube wells A_5, A_6, B_1 and B_3 mechanical analyses were made of percussion drill cuttings recovered by bailer and for exploratory borings BH_1, K_2 and KH_1 the analyses were made of samples obtained by coring. A list of the exploratory borings and tube wells for which mechanical analyses of samples were made and the number of analyses made for each is given below in Table 28. The complete mechanical analysis data for each of the borings and tube wells is given in Appendix 10.

TABLE 28

No. of exploratory boring or tube well	No. of mechanical analyses	No. of exploratory boring or tube well	No. of mechanical analyses
EB—A_2	10	TW—B_3	12
EB—A_3	39	EB—BH_1	8
TW—A_5	10	EB—K_2	17
EB—AA_5	10	EB—KH_1	24
TW—A_6	13	EB—N_1	11
TW—B_1	13		
		TOTAL	167

In order to determine the general water-yielding capacity of the principal water-bearing zones encountered in the exploratory borings, each of these was subjected to from 2 to 5 yield tests during which the static water level, maximum discharge and drawdown were observed. A list of the exploratory borings and the number of yield tests carried out at each is given below in Table 29. Complete observational data on each yield test for each boring as based on data supplied by the drilling contractors is given in Appendix 11.

TABLE 29

No. of exploratory boring	No. of yield tests	No. of exploratory boring	No. of yield tests
A_3	2	KH_1	4
AA_5	4	N_1	2
BH_1	4	N_2	4
K_2	5		
		TOTAL	25

In the yield tests made at exploratory boring A_3, a Beresford submersible pump and a Cook Deep Well turbine pump were used but in the tests made at the other borings an air compressor of 160 cubic feet per minute capacity and generally with 6-inch eductor pipe and 2-inch air pipe was used for pumping. Discharges were measured in a rectangular baffled tank with a V-notch weir. The yield tests were made by pumping from aquifers exposed in an open uncased hole penetrating relatively soft and friable Bhuj sandstones. Consequently caving occurred in the borings from time to time during the tests resulting in fluctuations in drawdown and discharge. The figures given in items K, L, M, of Appendix 11, that is, maximum pumping water level, maximum drawdown and average rate of pumping are thus averages rather than absolute measurements. The relative water-yielding capacities of the several water-bearing zones encountered by the exploratory borings are shown in Tables 11 and 12 and are discussed under "Water-bearing properties" of the Upper and Lower Bhuj series.

During the yield tests of the exploratory borings duplicate water samples were collected from each of the water-bearing zones tested and partial analyses were made in the Sindhu Resettlement Corporation Laboratory in Gandhidham and the

Imperial Chemical Industries Laboratory in Ahmedabad. Altogether some 57 partial analyses were made for 8 exploratory borings. These data are given in detail in Appendix 5 and are discussed in the section of this report on "Salinity in deep aquifers of the Bhuj series" under Chemical Quality of the Ground Water.

GROUND WATER CONDITIONS IN THE VIRI AREA

Drainage and topography

The Viri area, here described, includes a large inlier of Upper Bhuj sediments and contiguous hills of Deccan trap lying near the village of Viri which is about 2 miles southwest of Anjar (Plate 1). The inlier of Upper Bhuj sediments in the Viri area occupies a two-pronged valley or lowland which has been formed by erosional breaching of a pre-existing cover of Deccan trap. (See Plates 5-8.) The valley and the contiguous hills of Deccan trap are drained by Viri *Nala* and its tributaries which flow into the Sang River at Viri reservior (Plate 5). Viri *Nala* and its tributaries are, for the most part, ephemeral streams. However, in an area about ¼ mile southeast of Viri (Plate 5) are several springs and seeps which rise in the *nala* and the adjacent valley floor. The aggregate spring flow just above Viri reservoir was about one cubic foot per second in June 1951. In addition the Sang River also carries a small perennial spring fed flow which in June 1951 was about ¾ cubic foot per second near Viri reservoir.

The elevation of the valley floor ranges from about 300 feet above sea level near the northwest corner of the map area (Plate 5) to 190 feet at Viri reservoir. Contiguous trap hills rise from about 50 to 75 feet above the adjacent valley floor.

Geological features

The Viri area lies along the crest of the Shinaya anticline which is marked by southerly dips of 2 or 3 degrees in the Deccan trap to the south of the Viri inlier and easterly dips of similar magnitude in the trap near Sang River and Viri reservoir (Plate 1). The axis of Shinaya anticline trends northwest and passes along the southwestern margin of Viri reservoir to the vicinity of well 28P (Plate 1).

The oldest rock group in the Viri area is the Upper Bhuj series which is exposed or thinly covered by soil in the Viri inlier and several smaller adjacent inliers (Plate 5). As indicated by exploratory boring A_3 (Appendix 8) the Upper Bhuj series is at least

350 feet thick in the Viri area. Elsewhere, the Upper Bhuj series is overlain by lava flows of the Deccan trap whose thickness in the area ranges from a feather edge to as much as 200 feet or more.

The lithologic data obtained from exploratory boring A_2 (Appendix 8) and the production tube wells A_5, A_6, B_1 and B_3 (Appendix 9) indicate that Upper Bhuj series of the Viri area consists predominantly of medium to coarse, soft, friable sandstones intercalated with minor shales and siltstones. The Upper Bhuj sandstones, as is true in other parts of the Anjar-Khedoi region, are moderately to highly permeable. Moreover, the exploratory boring A_3 as well as the tube wells have shown that several productive aquifers occur in the Upper Bhuj between the land surface and a depth of 50 feet. (See Appendices 8 and 9).

The lava flows of the Deccan trap whose lithology has been described in a previous section of this report form a cover of varying thickness over the Upper Bhuj series in a large part of the Viri area. The trap sequence contains a ground-water body of relatively minor importance which is apparently perched with respect to water in the Upper Bhuj series.

GROUND WATER IN UPPER BHUJ AQUIFERS OF THE VIRI AREA

Source, movement and disposal of the ground water

The most important ground-water body in the Viri area occurs in the Upper Bhuj series. Moreover, this ground-water body is hydrologically interconnected with that of the Upper Bhuj of the Khamra lowland (Plate 1). The ground water in the Upper Bhuj of the Viri area is sustained and recharged by (1) direct penetration from precipitation on the surface of the Viri inlier, (2) infiltration from Viri *Nala* and Sang River while in spate, (3) return seepage from irrigation, (4) ground-water inflow that moves eastward from the Khamra lowland into the Viri inlier and (5) leakage from the perched ground-water body in the Deccan trap. The principal recharge to the ground-water body occurs during the southwest monsoon when precipitation is greatest and the streams are in spate.

The upper limit of the shallow ground water in the Upper Bhuj series is marked by a water table. In the Viri inlier the water table crops out at the surface in springs or lies with 10 feet of the land surface in the phreatophyte tract shown in Plates 5-8. Elsewhere in the Viri inlier the water table was from 11 to 30 feet below the land surface in 1951. The position, shape and slope of the water table in the shallow ground water of the Upper Bhuj series of the Viri area is shown in Plates 5, 6 and 7 by means of 2-foot contour referred to sea level. Plate 5 shows the position of the water table in June 1951 at the end of the 1950-51 dry season and Plate 7 shows the position in May 1952 near the end of the 1951-52 dry season. The position of the water table following the weak monsoon of 1951 is shown for October-November 1951 in Plate 6. The contours for all 3 seasons of Plates 5-7 show a general eastward slope of the water table from the direction of the Khamra lowland into the Viri inlier. In Plate 5 the contours for June 1951 indicate a strong trough in the water table developed along the Viri lowland which may have been the effect of prolonged dry season discharge by evapotranspiration in the phreatophyte tract and by springs. A minor trough centered around well 64 was apparently the result of ground-water withdrawals for irrigation. By October-November 1951 (Plate 6) this trough was largely obliterated probably largely as a result of ground-water recharge during the 1951 monsoon. Pumping from the Viri tube wells began in November 1951 and continued through the 1951-52 dry season. As a result of this pumping and withdrawals for irrigation a pronounced trough was developed in the water table that trended northwest through tube wells A_5, B_1 and B_3 (Plate 7).

Discharge of ground water from Upper Bhuj aquifers of the Viri area takes place by (1) evapotranspiration in the phreatophyte tract of the Viri lowland (Plate 5), (2) spring flow, (3) withdrawals from wells for irrigation and (4) pumping from the tube wells for the Gandhidham-Kandla Port water supply. During June 1951 it was estimated that the average ground-water discharge by evapotranspiration from the 68-acre phreatophyte tract was approximately one acre-foot per day or roughly 271,000 Imperial gallons a day. Discharge by spring flow in the Viri area during June 1951 was at the rate of approximately 1¾ cubic feet per second or roughly 942,000 Imperial gallons a day. Moreover, withdrawals of ground water from wells for irrigation was at an average rate of approximately 400,000 Imperial gallons a day. Thus in June 1951 the total daily artificial and natural discharge from Upper Bhuj aquifers of the Viri area was at the rate of about 1,613,000 Imperial gallons a day.

Since November 1951 the Viri tube wells have been used continuously for the Gandhidham-Kandla Port water supply and the daily pumpage has gradually increased from about 100,000 to 500,000 gallons a day. During May 1954 the daily pumpage from the tube wells ranged from 504,000 to 700,000 gallons per day with an average use of 582,000 gallons per day. (See Appendix 14.) As a result of the additional draft from the Viri tube wells, it is inferred that a large part of the water which formerly (June 1951) flowed from the springs to waste had been diverted underground by pumping to the tube wells by May 1954.

Present utilization of the ground water

A detailed inventory during 1951 indicated that there were 35 active irrigation wells in Upper Bhuj aquifers of the Viri area used to irrigate some 133 acres of fruit and vegetable crops. Wells 9P and 25P first of open, dug construction were subsequently deepened by boring to 78 and 145 feet, respectively. Other wells of the area were of simple open construction and generally less than 40 feet deep. As of June 1951 only well 25P was equipped with a horizontal centrifugal pump having a yield of 120 gallons a minute. The rest of the irrigation wells were all pumped by "motes" and bullocks at rates ranging from 8,000 to 36,000 gallons a day. The average daily draft from the irrigation wells during 1951 was at the rate of approximately 400,000 gallons a day or about 535 acre-feet per year.

During 1951 there were 5 tube wells constructed for the Gandhidham-Kandla Port water supply in the Viri inlier that range from 155 to 228 feet deep and whose initial yields ranged from 417 to 683 Imperial gallons a minute. Construction details and hydrologic data for these wells are given in Table 16. As of May 1954 three of the Viri tube wells were equipped with deep-well turbine pumps, one was pumped intermittently by air lift and one was used as an observation well. During May 1954 the average pumpage from the 3 operating wells was 582,000 gallons a day. Thus if it can be assumed that withdrawals from wells for irrigation was about the same as in 1951, then the total draft during May 1954 from Upper Bhuj aquifers of the Viri area for irrigation and for the public supply of Gandhidham-Kandla Port was slightly less than one million (10 lakhs) gallons a day.

Pumping test at the Viri tube wells

In order to ascertain the hydrologic properties of Upper Bhuj sandstone aquifers of the Viri area as well as the interference effects of the tube wells on the water levels of one another during pumping, two pumping tests were made during late October and early November 1951. During the first test tube well A_6 was pumped for about 24 hours on October 29-30, 1951 and water levels were measured before, during and after the test in the pumped well and in tube wells A_3, A_5, B_1 and B_3 and shallow well 3. Hydrographs of the 5 observation wells during the period of the test are given in Figure 9. As indicated by these hydrographs the lowering of water level caused by pumping in tube well A_5 was greatest in tube wells A_3 and B_3, and was least in shallow well 3.

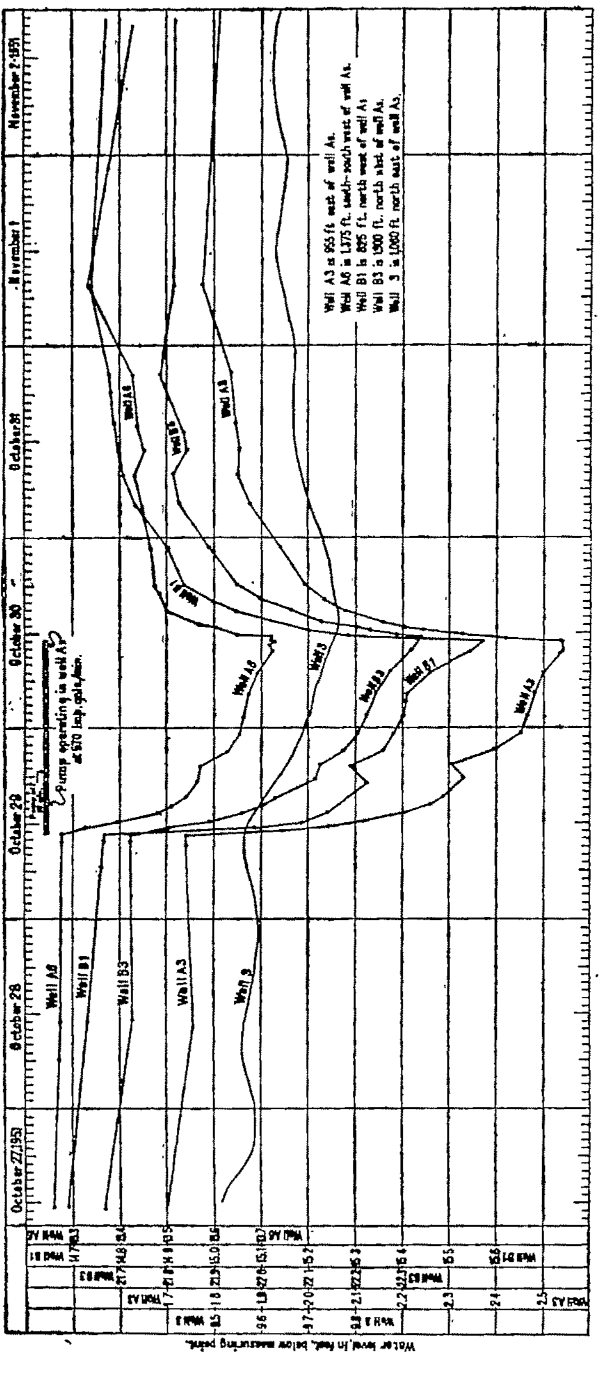


Figure 9 Hydrographs of four deep tube wells and one shallow dug well in the Viri area showing fluctuations of water levels during pumping of well A5, October-November 1951.

A second pumping test also of about 24 hours duration was made on tube well B_3 on November 5-6, 1951 and water levels were measured during the test in the pumped well and the other 4 tube wells of the Viri area. It is noted that water level of tube well B_1 was the most markedly effected by pumping in tube well B_3 and that of tube well A_6 was the least effected.

A water-bearing material or aquifer has two important properties with respect to its capacity to yield water to wells and these are its permeability and storage capacity (McGuinness *et al.*, 1949, pp. 57-58). The permeability of an aquifer is the volume of flow per unit time per unit cross section of the material per unit hydraulic gradient. For field use permeability may be expressed as the number of gallons of water per day that will flow through each mile of the aquifer (measured at right angles to the direction of flow) for each foot of thickness of the aquifer and each foot per mile of hydraulic gradient under local conditions of temperature.

The permeability multiplied by the thickness of the aquifer is known as transmissibility. The transmissibility may also be expressed as the rate of flow, in gallons per day, through each mile of the aquifer (measured at right angles to the direction of flow) for each foot per mile of hydraulic gradient.

The storage capacity of an aquifer is measured by its coefficient of storage, which is defined as the volume of water released from storage in a vertical prism of the aquifer of unit cross section by a unit decline in head. For field use the coefficient of storage may be expressed as the amount of water, in cubic feet, released from storage in each vertical prism of the aquifer with a cross-sectional area of one square foot as the head declines one foot. Under water-table conditions the coefficient of storage approaches the specific yield which is the ratio of the volume of water which the saturated aquifer will yield by gravity to the volume of the aquifer.

Several formulae for the determination of the hydrologic properties of aquifers have been developed by C. V. Theis, L. K. Wenzel, C. E. Jacob and others of the U. S. Geological Survey. By means of these formulae applied to data from pumping tests, the transmissibility and storage coefficients of an aquifer can be determined and these can be used to predict the effect of pumping a given quantity of water for any given period not only in the pumped wells but also in other adjacent wells tapping the same aquifer (Wenzel, L. K., 1942). The formulae can also be used to determine the quantity of water that can be pumped from a given well or wells with specified drawdowns in the pumped well or other wells. Adequate pumping tests thus afford a means of making quantitative estimates of the water supply of an aquifer.

Computations of transmissibility from the pumping test data of tube wells A_5 and B_3 by the Theis (1935, pp. 519-524) formula indicate values of about 157,000 and 64,000 U.S. gallons per day per foot, respectively. These values appear to be of the right order of magnitude for sandstone aquifers such as those of the Upper Bhuj of the Viri area. The coefficients of storage obtained from the pumping effect of tube well A_5 on other tube wells of the Viri area range from 1×10^{-3} to 4×10^{-4}. These coefficients indicate that confined or artesian conditions exist in the deeper Upper Bhuj aquifers of the Viri area. However, the shallow ground water tapped by most of the dug irrigation wells is evidently under water-table or unconfined conditions although it is hydrologically interconnected with the deeper confined aquifers. Thus the water-table contours of Plates 5-7 probably reflect the hydraulic gradients prevailing in the deeper Upper Bhuj aquifers as well as those in the shallow ground water.

The water-table contours for October-November 1951 suggest an easterly and southeasterly movement of ground water into the Viri inlier at a hydraulic gradient of approximately 16 feet per mile and across a front of about 7,000 feet. If the average transmissibility of the Upper Bhuj aquifers of the area can be taken as about 100,000 U. S. gallons per day per foot, then there were roughly about 1,700,000 Imperial gallons per day moving through Upper Bhuj aquifers toward the Viri inlier during October-November 1951. This figure compares reasonably well with a figure of 1,613,000 Imperial gallons per day previously estimated as the total natural and artificial ground-water discharge from Upper Bhuj aquifers of the Viri area during June 1951.

Chemical quality of the ground water in the Viri area

Owing to the initial importance of the Viri area as a source of ground-water supply for the Gandhidham-Kandla Port development numerous chemical analyses have been made of waters from wells of the area. Chemical data which refer specifically to wells in the Viri area are given in Appendices 6 and 7 and other data for Viri area wells are included in Appendices 1, 4 and 5. The significance of these analytical data has already been discussed in a previous section of this report under "Chemical quality of the ground water".

Based on analytical data given in Appendix 1 a map was prepared showing the distribution of chlorides in the shallow ground water of the Upper Bhuj series of the Viri area during June 1951. (See Plate 8.) The chloride content also reflects the general salinity of the ground water. It is observed in Plate 8 that the chloride content progressively increases from northwest to southeast across the Viri inlier. On the northwest the chloride content is less than 100 parts per million but on the southeast it increases to more than 1,000 ppm. The high chloride belt on the southeast is believed to be related to concentration of salts in the ground water by evapotranspiration in the phreatophyte tract (Plate 8). On the northwest side of the Viri inlier the shallow ground water generally contains less than 300 ppm of chlorides and is suitable for public water supply and for irrigation. Centered near the village of Viri is a patch of moderately high chlorides (up to 500 ppm) that may be the result of local saline seepage from human and animal ordure.

The available analytical data indicate considerable variability in the chemical quality of the ground water in deep aquifers tapped by the tube wells of the Viri area. Based on data from Appendix 6, the content of total dissolved solids in the waters of the tube wells at the time of their construction in 1951 is shown comparatively in Table 30 below:

TABLE 30

Well No.	Depth (feet)	Total dissolved solids (ppm)
A_3	220	902
A_5	210	838
A_6	155	764
B_1	220	636
B_3	115	470

It is noted that there is a progressive increase in salinity of the water from B_3 through B_1 and A_5 to A_3 (Plate 8). The quality of the water of well A_6 lies between that of wells B_1 and A_5 (Table 30). Generally, to west of the 300 ppm isochlor which passes through the center of the phreatophyte tract (Plate 8) it is observed that the ground water is of good to fair chemical quality from the land surface down to depths of 175 to 225 feet. East of this 300 ppm isochlor the ground water becomes increasingly saline with successively deeper aquifers. It is inferred on the basis of existing data that the water in all aquifers below depths of 250 feet in all of the Viri inlier is generally moderately to markedly brackish.

Perennial yield of ground water in the Viri area

The average quantity of ground water that is available year after year for withdrawals from wells in the Viri area is the perennial yield. This quantity is essentially equivalent to the local long-term average recharge plus water transmitted through Upper Bhuj aquifers into the Viri inlier plus salvagable natural dischrage. However, the presence of a zone of brackish water on the south-east side of the inlier makes full development of the ground-water potentialities unfeasible without risking the danger of brackish water contamination of the tube wells.

Based on estimates and computations previously discussed, it is believed that the total pumpage from the tube wells of the Viri area should not exceed 700,000 (7 lakhs) Imperial gallons per day with an optimum draft averaging about 500,000 (5 lakhs) gallons per day. If this pumpage is exceeded for a prolonged period there is strong probability of contamination of the water of the tube wells by the encroachment of brackish water from the southeast side of the inlier. Moreover, to minimize the possibility of such brackish water contamination it is believed that pumping should be concentrated in tube wells B_1 and B_3 although well A_5 can also be pumped from time to time. Tube well A_3 can be left for standby use and well A_6 is convenient as an observation well. Excessive pumping in the Viri tube wells would also with time have marked lowering effects on the water levels of shallow irrigation wells because the shallow ground water as shown by the present study is interconnected although indirectly with that in the deeper aquifers tapped by the tube wells.

FUTURE DEVELOPMENT OF GROUND WATER

From the results of the present investigation it is estimated that the long-term safe yield from the ground-water body in the Upper Bhuj series of the Anjar-Khedoi region is of the order of 10,000 to 12,000 acre-feet per year. The rate of ground-water withdrawal during 1951-54 from existing irrigation wells of the region plus that from the Viri tube wells is roughly equivalent to and may even slightly exceed the estimated safe yield. Therefore, additional draft on the ground-water body from new tube wells put down for the Gandhidham-Kandla Port water supply would eventually have adverse effects on the water levels and yields of existing irrigation wells. Likewise, the draft from the irrigation wells would also adversely affect any new tube wells constructed. Hence, effective compensatory measures are very likely to be required to correct this situation if the permanence of new water supplies from tube wells developed for the Gandhidham-Kandla Port requirements in the Anjar-Khedoi region is to be assured.

If a legal priority of the Gandhidham-Kandla Port water supply requirements over that for existing irrigation use can be assumed, then it is possible to outline a plan for future groundwater development. Sites for new tube wells should be carefully selected so as to minimize as far as possible interference effects on existing wells and to avoid the possible eventuality of brackish water contamination. With respect to the Gandhidham-Kandla Port water supply the following sites for construction of tube wells in the Khamra lowland are suggested:

(1) A site 1⅛ miles south-southwest of Khamra and 1½ furlongs southeast of well 535 (Plate 1).

(2) A site 1¼ miles east of Khamra and 1½ furlongs northwest of well 2 (Plate 1).

(3) A site 1¼ miles northwest of Mota Nagalpur and one-half mile south-southeast of well 297 (Plate 1).

(4) A site 1⅛ miles north-northwest of Mota Nagalpur, 7½ furlongs east of exploratory boring BH_1 (Plate 1).

(5) A site about one-quarter mile northwest of exploratory boring BH_1 (Plate 1).

(6) A site about 7 furlongs west-southwest of well 7 (Plate 1) and 1¼ miles northeast of Mota Nagalpur.

At these sites the water table is generally less than 50 feet from the land surface, permeable and productive aquifers are present to a depth of several hundred feet below the land surface and the ground water is of fair to good chemical quality. At each of these sites the requisite depth of drilling would be about 350 to 400 feet. In each case it is suggested that the well be drilled in such a manner that blank 12-inch (I.D.) casing can be set from the surface to a depth of about 150 feet. Through water-bearing strata between 150 and 350 to 400 feet, the well should be drilled so as to accommodate either (1) a 10-inch (I.D.) prefabricated well screen (strainer) or (2) a 10-inch (I.D.) slotted casing with an appropriate gravel shroud (envelope). The water-bearing materials at the sites indicated are medium to coarse-grained, soft, friable sandstones. Thus the well screens selected for these materials should have slot openings of such width as to retain approximately two-thirds of the sand sizes and allow one-third of them to enter the well and be pumped out. In this manner a natural envelope of coarse sand and fine gravel will be gradually built up around the well screen. Alternatively slotted casing with gravel shrouding can be placed in the water-bearing horizons between 150 and 350 to 400 feet. In such case the gravel used for shrouding should preferably be ⅛-inch to ¼-inch in diameter if natural and ¼-inch to ½-inch if crushed rock. After completion each well should be thoroughly developed by pumping, surging and backwashing in order to remove the finer sand and silt sizes from in and around the well envelope.

In order to minimize local drawdowns in water level, it is suggested that the pumping draft from each tube well be maintained at an optimum of 300,000 (3 lakhs) gallons a day or less. This would call for a daily 10-hour pumping schedule at each tube well at the rate of 30,000 gallons per hour. Thus with 5 supply wells and with one well for standby or emergency use, about 1½ million (15 lakhs) gallons a day could be developed from wells at the sites suggested in the Khamra lowland.

If additional ground-water supplies for Gandhidham-Kandla Port, as outlined above, are to be developed from tube wells in the Anjar-Khedoi region, it will not be desirable or feasible to permit expansion of present ground-water consumption for irrigation. Indeed, sharply restrictive measures leading to reduction in the present use for irrigation are likely to be required. Moreover, if ground-water supplies, beyond the 1½ million gallon a day supply just outlined, must necessarily be developed from Upper Bhuj aquifers in the Anjar-Khedoi region, then actual appropriation of existing rights to use of the ground water for irrigation may be required. Alternatively it is considered feasible to develop ground-water supply totalling about 2 million (20 lakhs) gallons a day from the Dudhai (Taylor and Oza, 1954) and the Bhachau areas together of eastern Kutch without excessive interference to the supplies of existing irrigation wells. However, owing to greater distance from the Gandhidham-Kandla Port area, ground-water supplies from the Dudhai and Bhachau areas would be somewhat more costly to develop than those from the Anjar-Khedoi region.

With the foregoing considerations in view it is believed that all measures should be taken to utilize and develop existing and potential reservoirs for the storage of surface run-off in the

Gandhidham-Kandla Port hinterland so as to reduce the need for a continuous and heavy draft on the ground-water supply. As indicated in the report of the Kandla Port Water-Supply Committee (1949) there are several existing reservoirs in the Gandhidham-Kandla Port hinterland that are capable of utilization and other potential reservoir sites with relatively large catchment that can also be developed. The capabilities of surface-water resources of eastern Kutch have already been discussed in the light of existing data by M. B. Chablani (1949) and Sardar Mansingh (1949). Additional data regarding evaporation, local rainfall and monsoon run-off in the several stream systems of eastern Kutch are very much needed before surface-water resources can be properly evaluated.

REFERENCES

AUDEN, J. B.—Preliminary study of water supply, Cutch with particular reference to Kandla Port, Appendix III to the report of the Kandla Port Water Supply Committee; *Geol. Surv. of India* (*cyclostyled report*), 26 pp., May 1949.

AUDEN, J. B.—The bearing of geology on multipurpose projects; *Proceedings of the 38th Indian Science Congress*, part 2, pp. 109-153, 1951.

AUDEN, J. B.—Some geological and chemical aspects of the Rajasthan salt problem; *Bulletin of the National Institute of Sciences of India*, No. 1 (*Proceedings of the symposium on the Rajputana desert*), pp. 51-67, September 1952.

CHABLANI, M. B.—Surface resources for Kandla Water Supply (study of Viri reservoir), *Appendix VII to the report of the Kandla Port Water Supply Committee; Typed report*, 8 pp., 1949.

KRISHNAN, M. S.—*Geology of India and Burma;* The Madras Law Journal Press, Madras, 544 pp., 1949.

MANSINGH, SARDAR.—Annual run-off of reservoirs for Kandla Water Supply for the period of 1933-40, *Appendix V, to the report of the Kandla Port Water Supply Committee; Typed report*, 11 pp., 1949.

McGUINESS, C. L., POINDEXTER, O. F., OTTON, E. G.—Ground-Water supplies of the Ypsilanti area, Michigan; *U. S. Geological Survey Water-Supply Paper 1078*, 103 pp., 1949.

MEINZER, O. E.—Plants as indicators of ground water; *U. S. Geological Survey Water-Supply Paper 577*, 95 pp., 15 figs., 12 pls., 1927.

PATHAK, B. D.—Progress report of drilling, Viri area, Kutch; *Geol. Surv. of India* (*cyclostyled report*), 5 pp., September 1950.

PATHAK, B. D.—Note on the examination of bore hole samples from Kandla Port, Kutch; *Geol. Surv. of India* (*cyclostyled report*), 3 pp., September 1950.

PATHAK, B. D.—Preliminary examination of concrete aggregate sites for Kandla Port project, Kutch; *Geol. Surv. of India* (*cyclostyled report*), 3 pp., June 1951.

PATHAK, B. D.—Progress of geological and ground-water investigations for the water supply of Kandla Port; *Geol. Surv. of India* (*cyclostyled report*), 14 pp., December 1951.

RAJNATH.—A contribution to the stratigraphy of Kutch; *Quarterly Journal of the Geological, Mining and Metallurgical Society of India*, Vol. 4, No. 4, pp. 161-174, 1932.

RAJNATH.—The Jurassic rocks of Kutch—their bearing on some problems of Indian geology; *Proceedings of the 29th Indian Science Congress*, part 2, pp. 93-106, 1942.

SAHA, A. K.—A short note on ground-water studies in the garden area north of Anjar, Kutch; *Geol. Surv. of India* (*cyclostyled report*), 5 pp., May 1951.

SCOFIELD, C. S.—South Coastal Basin investigation, quality of irrigation waters: *California Deptt. of Public Works, Div. of Water Resources, Bull. 40*, pp. 21-24, 1933.

SEN GUPTA, S. N.—Note on the geophysical investigation of ground water at Kandla Port, Cutch; *Geol. Surv. of India (cyclostyled report).*

TAYLOR, G. C., JR., AND OZA, M. M.—Geology and ground water of the Dudhai area, eastern Kutch; *Geol. Surv. of India Bull., Series B*, No. 5, 73 pp., 1954.

THEIS, C. V.—The relation between the lowering of the peizometric surface and the rate and duration of discharge of a well using ground-water storage; *Trans. American Geophs. Union*, pp. 519-524, August 1935.

TREWARTHA, GLENN T.—*An introduction to weather and climate*; McGraw-Hill Book Company, Inc., New York, 545 pp., 1943.

WAAGEN, WILLIAM.—Jurassic fauna of Kutch, Vol. 1, The Cephalopada; *Palaeontologia Indica, series IX*, Vol. 1, p. 1, 1873.

WENZEL, L. K.—Methods for determining permeability of water-bearing materials; *U. S. Geological Survey Water-Supply Paper 387*, 192 pp., 6 pls., 1942.

WHITE, W. N.—A method of estimating ground-water supplies based on discharge by plants and evaporation from the soil; *U. S. Geological Survey Water-Supply Paper 659-A*, 105 pp., 29 figs., 10 pls., 1932.

WYNNE, A. B.—Geology of Kutch; *Memoirs, Geological Survey of India*, Vol. IX, pt. 1, pp. 1-293, 1872.

APPENDICES

APPENDIX 1.

Results of chemical analyses for chlorides in water from shallow wells in the Anjar-Khedoi region.

(*Analyses by Sindhu Resettlement Corporation Laboratory, Gandhidham.*)
(Chloride content, in parts per million)

Well No.	Chloride content	Date of collection of sample	Well No.	Chloride content	Date of collection of sample
1P	296	June 4, 1951	26	83	Jan. 23, 1952
2P	353	Ditto	27	533	Feb. 3, 1952
3P	732	Ditto	28	91	Ditto
10P	324	Feb. 2, 1952	30	678	Ditto
13P	191	Ditto	38	1,672	May 9, 1952
14P	905	Ditto	40	170	June 3, 1951
16P	1,455	Ditto	41	201	Ditto
20P	614	Ditto	42	193	Ditto
21P	227	June 2, 1951	46	1,513	June 4, 1951
22P	84	June 3, 1951	48	35	June 3, 1951
28P	113	June 4, 1951	49	381	Ditto
37P	1,273	Feb. 3, 1952	50	149	Ditto
S2	638	Ditto	51	472	Ditto
S6	396	Ditto	52	268	June 2, 1951
S7	900	Feb. 7, 1952	53	123	Feb. 3, 1952
S8	162	Feb. 3, 1952	54	108	June 2, 1951
S10	39	Ditto	55	139	Ditto
S14	421	Ditto	56	106	Ditto
S15	72	Ditto	57	509	Ditto
S16	43	Ditto	58	462	Ditto
S18	224	Ditto	59	352	June 3, 1951
S19	215	Ditto	60	83	Ditto
S20	122	Ditto	61	600	Ditto
S22	266	Ditto	63	8	Ditto
S26	169	Ditto	64	169	June 2, 1951
S31	48	Ditto	65	42	Ditto
S32	209	Feb. 7, 1952	66	53	Ditto
S34	58	Ditto	67	357	June 3, 1951
S36	115	Ditto	68	105	Ditto
S37	59	Ditto	69	135	Ditto
S38	60	Ditto	70	153	Feb. 3, 1952
S39	58	Ditto	71	201	Ditto
S40	60	Ditto	72	492	Ditto
S41	525	Feb. 3, 1952	73	252	Ditto
S42	338	Ditto	74	778	Ditto
S46	162	Ditto	75	1,308	Ditto
S48	229	Ditto	76	174	Jan. 30, 1952
S51	1,930	Ditto	77	242	Feb. 7, 1952
S53	273	Feb. 4, 1952	79	60	Ditto
1	1,258	Feb. 8, 1952	82	95	Ditto
5	179	Ditto	83	445	Jan. 23, 1952
7	114	Feb. 4, 1952	84	528	Ditto
9	881	Feb. 16, 1952	85	683	Ditto
12	173	Feb. 2, 1952	86	111	Feb. 7, 1952
13	59	Ditto	87	47	Ditto
14	266	Feb. 7, 1952	91	341	Ditto
15	183	Feb. 8, 1952	93	348	Ditto

APPENDIX 1—*contd.*

Well No.	Chloride content	Date of collection of sample	Well No.	Chloride content	Date of collection of sample
16	269	Feb. 8, 1952	95	264	Jan. 26, 1952
17	43	Jan. 23, 1952	96	536	Feb. 2, 1952
18	87	Feb. 10, 1952	98	94	Jan. 30, 1952
19	357	June 2, 1951	102	81	Feb. 16, 1952
20	155	Ditto	103	137	Feb. 2. 1952
22	480	Jan. 24, 1952	105	654	Feb. 16, 1952
23	368	Jan. 23, 1952	106	192	Feb. 2, 1952
24	90	Jan. 29, 1952	107	47	Ditto
25	577	Ditto	109	360	Ditto
110	718	Feb. 16, 1952	259	73	Feb. 7, 1952
113	211	Feb. 8, 1952	261	52	Ditto
114	74	Feb. 9, 1952	263	33	Ditto
115	531	June 4, 1951	264	37	Ditto
117	120	Feb. 9, 1952	265	36	Ditto
118	71	Ditto	266	78	Ditto
119	123	Jan. 30, 1952	268	319	Ditto
121	1,188	Jan. 26, 1952	269	33	Ditto
122	392	Ditto	270	34	Ditto
123	559	Ditto	271	20	Ditto
124	1,401	Ditto	272	291	Feb. 8, 1952
126	55	Jan. 30, 1952	274	51	Ditto
127	688	Jan. 24, 1952	278	172	Ditto
128	40	Jan. 30, 1952	279	444	Ditto
129	319	Jan. 28, 1952	282	105	Ditto
133	342	Feb. 18, 1952	284	139	Ditto
158	284	Jan. 29, 1952	287	261	Ditto
160	111	Feb. 8, 1952	288	178	Ditto
162	1,395	Feb. 9, 1952	291	266	Ditto
163	156	Feb. 11, 1952	294	196	Ditto
164	333	Jan. 29, 1952	295	102	Ditto
166	1,225	Ditto	299	113	Jan. 24, 1952
167	128	Ditto	300	55	Ditto
169	284	Jan. 28, 1952	301	73	Ditto
171	278	Ditto	302	109	Ditto
172	59	Jan. 24, 1952	305	106	Ditto
174	107	Ditto	308	981	Ditto
175	430	Feb. 8, 1952	311	147	Ditto
177	71	Jan. 26, 1952	314	400	Ditto
183	543	Feb. 2, 1952	316	1,354	Ditto
186	107	Ditto	318	284	Ditto
187	1,840	Ditto	319	161	Ditto
188	279	Ditto	321	37	Ditto
190	132	Ditto	323	60	Ditto
196	104	Ditto	324	59	Ditto
198	462	Ditto	327	817	Ditto
205	551	Ditto	328	146	Ditto
209	60	Ditto	330	1,213	Ditto
210	81	Ditto	333	1,733	Ditto
211	525	Ditto	335	761	Ditto
213	21	Ditto	336	531	Ditto
217	585	Ditto	339	228	Ditto
222	47	Ditto	341	727	Jan. 26, 1952
224	84	Ditto	345	280	Jan. 24, 1952
225	97	Ditto	348	72	Ditto
226	67	Ditto	349	164	Ditto
227	374	Ditto	355	584	Jan. 26, 1952

APPENDIX 1—*contd.*

Well No.	Chloride content	Date of collection of sample	Well No.	Chloride content	Date of collection of sample
229	297	Feb. 2, 1952	356	1,344	Jan. 23, 1952
233	509	Feb. 3, 1952	359	387	Ditto
234	199	Feb. 9, 1952	360	551	Ditto
236	416	Ditto	361	341	Ditto
241	159	Ditto	363	1,055	Ditto
242	970	Feb. 8, 1952	364	391	Ditto
243	932	Ditto	367	1,083	Jan. 26, 1952
244	88	Feb. 7, 1952	369	941	Ditto
246	1,132	Ditto	377	2,686	Ditto
249	1,011	Feb. 8, 1952	381	659	Ditto
250	911	Ditto	382	223	Ditto
252	281	Ditto	383	1,876	Ditto
255	132	Ditto	389	128	Ditto
256	385	Ditto	396	136	Ditto
257	249	Feb. 9, 1952	398	185	Ditto
258	99	Feb. 7, 1952	401	698	Ditto
402	571	Jan. 26, 1952	538	152	Jan. 29, 1952
406	137	Jan. 28, 1952	539	277	Ditto
408	169	Ditto	542	305	Ditto
410	233	Ditto	543	618	Ditto
412	317	Jan. 31, 1952	545	339	Ditto
413	287	Ditto	548	1,430	Feb. 10, 1952
415	346	Ditto	549	598	Ditto
416	143	Ditto	551	451	Feb. 21, 1952
417	151	Jan. 28, 1952	555	165	May 11, 1952
419	558	Ditto	556	89	Ditto
422	242	Ditto	568	1,953	Feb. 10, 1952
423	208	Ditto	569	149	Ditto
424	472	May 9, 1952	573	163	Feb. 11, 1952
425	93	Ditto	575	381	Ditto
427	58	Ditto	582	92	Ditto
428	58	Ditto	583	1,422	Feb. 10, 1952
431	43	Jan. 28, 1952	586	80	Feb. 12, 1952
432	99	Ditto	590	178	Feb. 11, 1952
434	150	Jan. 29, 1952	591	336	Ditto
436	243	Ditto	596	90	Feb. 13, 1952
438	919	Ditto	599	47	Feb. 12, 1952
440	1,624	Ditto	603	1,421	Feb. 18, 1952
441	366	Ditto	606	1,794	Ditto
444	135	Ditto	607	1,493	Ditto
446	422	Ditto	608	1,551	Ditto
447	493	Ditto	621	68	Jan. 31, 1952
448	258	Ditto	622	76	Ditto
449	322	Jan. 28, 1952	623	105	Ditto
451	127	Feb. 8, 1952	624	143	Ditto
452	84	Ditto	625	879	Ditto
453	73	Feb. 9, 1952	626	558	Ditto
454	1,099	Feb. 10, 1952	628	528	Ditto
455	1,643	Ditto	630	199	Ditto
457	30	Ditto	631	635	Ditto
460	39	Jan. 23, 1952	632	115	Feb. 4, 1952
463	34	Ditto	634	69	Ditto
464	527	Jan. 31, 1952	636	67	Ditto
467	50	Jan. 26, 1952	637	410	Ditto
468	177	Jan. 23, 1952	638	427	Ditto
469	742	Ditto	641	529	Feb. 5, 1952

APPENDIX 1—*concld.*

Well No.	Chloride content	Date of collection of sample	Well No.	Chloride content	Date of collection of sample
470	396	Jan. 23, 1952	042	471	Feb. 5, 1952
471	1,134	Ditto	644	108	Ditto
472	143	Ditto	546	46	Ditto
478	1,312	Jan. 26, 1952	648	193	Ditto
487	219	Ditto	651	138	Ditto
491	450	Ditto	653	64	Ditto
494	119	Ditto	654	781	Feb. 9, 1952
495	73	Ditto	656	365	Ditto
497	396	Ditto	657	272	Ditto
498	1,142	Jan. 23, 1952	658	594	Ditto
501	130	Feb. 10, 1952	659	60	Ditto
505	268	Ditto	662	678	Ditto
507	348	Ditto	666	84	Ditto
508	236	Ditto	667	891	Feb. 10, 1952
513	90	Jan. 26, 1952	669	1,107	Ditto
517	1,170	Jan. 23, 1952	670	309	Ditto
518	1,647	Jan. 26, 1952	672	282	Ditto
529	84	Jan. 29, 1952	673	89	Feb. 12, 1952
530	377	Ditto	675	153	Ditto
533	1,913	Ditto	677	337	Ditto
534	1,623	Ditto	681	849	Ditto
524	1,887	Ditto	683	402	Feb. 13, 1952
536	172	Ditto	684	737	Ditto
685	188	Feb. 13, 1952	756	572	Apr. 26, 1952
686	326	Ditto	761	225	Ditto
688	527	Ditto	762	211	Ditto
690	97	Feb. 14, 1952	763	191	Ditto
691	74	Ditto	764	510	Apr. 30, 1952
694	78	Ditto	767	384	Ditto
696	127	Ditto	769	453	Ditto
698	435	Ditto	770	149	Ditto
699	1,810	Feb. 21, 1952			
700	1,873	Ditto	771	609	Ditto
707	427	Apr. 17, 1952	774	1,059	Ditto
709	131	Ditto	777	539	Ditto
711	404	Ditto	779	1,139	May 9, 1952
713	670	Ditto	781	2,460	Ditto
717	367	Apr. 25, 1952	782	1,457	Ditto
722	58	Ditto	784	397	Ditto
723	1,211	Ditto	787	102	Ditto
725	1,436	Ditto	788	70	May 11, 1952
727	1,182	Ditto	789	941	Ditto
729	184	Ditto	790	657	Ditto
731	405	Ditto			
732	160	Ditto	791	316	Ditto
737	1,835	Ditto	792	619	Ditto
740	552	Ditto	793	402	Ditto
743	358	Apr. 26, 1952	794	118	Ditto
744	422	Ditto	795	508	Ditto
747	839	Ditto			
754	293	Ditto	796	373	Ditto

APPENDIX 2.

Complete chemical analyses of waters from shallow wells in the Anjar-Khedoi region.

(*Analyses by Geological Survey of India Laboratory, Calcutta.*)

Analyzed by Mr. S. C. Chakravarty, *Assistant Chemist, Geological Survey of India, Calcutta.*

Well No.	Location	Date of collection (1951)	Temp. (°F.)	Analyses (parts per million)											
				Total solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO-)	Total hardness (as $CaCO_3$)
10	0·6 mile SW of Samparda	Feb. 25	84	556	38	Trace	73	23	76	1	209	46	156	20	275
14	1·5 miles W of Anjar	Feb. 27	88	1,456	52	do.	147	61	244	24	358	237	388	—	615
15	0·25 mile N of Nagalpur	do.	84	752	39	do.	54	28	154	3	269	97	176	5	250
18	0·5 mile N of Sidungra	do.		569	42	do.	55	26	77	2	257	82	118	8	242
19	0·6 mile SW of Viri	Feb. 28	83	1,214	31	do.	59	42	335	5	520	101	340	29	322
21	0·75 mile NE of Khedoi Mota	Mar. 1		481	28	do.	56	17	95	1	179	45	127	12	210
28	1·25 miles NNW of Anjar	do.	85	529	34	do.	69	18	80	4	247	25	123	6	247
31	At Agriculture Station, Gandhidham (Adipur)	Mar. 3	88	2,353	26	do.	22	20	837	—	735	278	764	—	138
37	1·25 miles NNW of Nigal	Mar. 4	84	2,895	32	do.	226	103	525	12	257	468	1,051	—	1,015
45	S. edge of Sardarganj	Mar. 7	87	10,088	32	do.	210	205	3,466	27	400	357	5,325	41	1,875

APPENDIX 3.

Partial chemical analyses of waters from shallow wells in the Anjar-Khedoi region.

(*Analyses by Geological Survey of India Laboratory, Calcutta.*)

Analyzed by Mr. M. K. De, *Assistant Chemist, Geological Survey of India, Calcutta.*

Well No.	Location	Date of collection (1951)	Temp. (°F.)	Analyses (parts per million)				
				Total solids	Silica (SiO_2)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)
13	0·5 mile W of Anjar	Feb. 27	84	568	36	203	38	80
16	0·25 mile SSW of Nagalpur . . .	do.	83	918	24	156	91	280
20	0·36 mile W. of Viri	Feb. 28	85	551	41	101	33	120
22	W. outskirts of Khedoi Nana . . .	Mar. 1	84	1,272	38	151	165	440
24	0·5 mile S. of Khamra	do.		408	28	108	28	100
32	At factory in Gandhidham . . .	Mar. 3	88	2,612	44	448	296	950
38	0.75 mile SSE of Nigal	Mar. 4	83	5,888	70	178	1,355	2,100

APPENDIX 4.

Chemical analyses of waters from shallow wells near Viri, Shinaya and Kidana.

(Analyses by Sindhu Resettlement Corporation Laboratory, Gandhidham.)

Analyzed by Mr. M. G. Gulrajani, *Chemist, Sindhu Resettlement Corporation, Gandhidham.*

Well No.	Location	Date of collection	Temp. (°F)	Analyses (in parts per million)										
				Total solids @105°C	Silica (SiO$_2$)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium & Potassium (Na + K	Bicarbonate (HCO$_3$)	Sulphate (SO$_4$)	Chloride (Cl)	Nitrate (NO)	Total hardness (as CaCO$_3$)
2P	0·15 mile E of Viri	May 7, 1951	82	1,225	43					260	42	301		340
7P	0·12 mile NE of Viri	May 5, 1951	86	1,003	39					208	105	323		360
9 P	0·18 mile NNE of Viri	do.		593	40					153	20	147		260
24P	0·4 mile S of Viri	Apr. 23, 1951		1,959	44					294	109	753		516
25P	0·6 mile SSE of Viri	May 7, 1951	88	2,570	60					219	21	1,119		524
26P	0·5 mile S of Viri	Apr. 23, 1951		1,703	13	Nil	23	31	658	575	66	337	1	28

7 P	0·25 mile E of Viri	May 5, 1951		2,808	20					126	122	1,366		820
32P	Ditto	May 7, 1951	88	2,444	54					204	128	1,124		747
41	0·5 mile SSW of Viri	Apr. 23, 1951		1,164	39	Nil	11	8	467	389	33	204	12	54
47	0·62 mile SW of Viri	May 7, 1951		2,184	47					162	105	1,038		735
69	0·37 mile SSW of Viri	Apr. 23, 1951		851	24					316	22	131		67
138	0·12 mile SE of Shinaya	Feb. 18, 1952		1,300	55					435	85	388		376
600	1·5 miles E of Shinaya	do.	80	2,438	35					569	210	887		340
605	0·8 mile SE of Kidana	do.		3,095	49					246	188	2,073		1,480

APPENDIX 5.

Partial chemical analyses of waters from deep exploratory borings in the Anjar-Khedoi region.

(Analyses by Sindhu Resettlement Corporation Laboratory, Gandhidham and Imperial Chemical Industries Laboratory, Ahmedabad.)

Exploratory boring, A_3, located one and a half furlongs south of Viri. Finished as tube well A_3.

Water-bearing zone sampled	Date of sampling	Total solids at 105°C		Silica (SiO_2)		Sulphate (SO_4)		Chloride (Cl)		Nitrate (NO_3)		Total hardness as $CaCO_3$		pH value	
		Analyses (in parts per million)													
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
@ 75 feet	July 31	918*	982†		45†		85†	261*				290*	280†	8·6*	7·3†
@ 150 feet	Aug. 7	936	1,024		22		114	260				268	308		7·5
0—130 feet	Sept. 2	861	924		28		99	220				316	260		7·3
@ 220 feet	Oct. 2	1,999	1,076		22	68*	65	779		Nil*		328	306		7·5
@ 320 feet	Oct. 5	1,386				77		494		Nil		394			
400—450 feet	Oct. 27	992				100		348		Nil		260			
@ 550 feet	Nov. 15	1,684†	1,418		27	79	108	641		Trace		408	350		7·4
@ 540 feet	Dec. 18	3,246†				162		1,893				800			

* *Analysis by SRC Laboratory.*
† *Analysis by ICI Laboratory.*

Exploratory boring, A_2, located 3 furlongs SE of Viri and 975 ft. SE of tube well A_3. Destroyed.

	(1951)	Analyses (in parts per million)													
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
0—206 feet	Mar. 10	5,751*				690*		2,867*		Nil*		1,660*			

Analysis by SRC Laboratory.

Exploratory boring, AA_5, located 2 furlongs SW of Viri and 20 feet NW of tube well A_5. Destroyed.

	(1950)	Analyses (in parts per million)													
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
@ 90 feet	Aug. 16	758*	796†		55†		68†	177*		5*		278*	240†		7·5†
125—154 feet	Aug. 31	902	922		27		99	228				242	260		7·5
@154 feet	Aug. 25	765	818		28		99	215				247	218		7·6
@175 feet	Sept. 1	900	954		27		99	230				277	268		7·3

**Analysis by SRC Laboratory.*
†Analysis by ICI Laboratory.

APPENDIX 5—*contd.*

Exploratory boring, BH_1, located 1 5/8 miles SE of Bhadroi. Destroyed.

	(1951)	Analyses (in parts per million)													
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	14	(15)	(16)
90—260 feet	Nov. 10	338*	432†	Nil*	72†	25*		62*		6*		208*	180		7·5*
280—385 feet	Dec. 12	356	398	Trace	19	23		74		9		185	188		7·5
280—590 feet	Dec. 15	978	1,056	Trace	23	254		245		20		275	298		7·5
280—700 feet	Dec. 22	889	968	Trace	19	308		205		18		255	244		7·4

*Analysis by SRC Laboratory.
†Analysis by ICI Laboratory.

Exploratory boring, K_2, located one furlong NNW of Khedoi Mota. Destroyed.

	(1951)	Analyses (in parts per million)													
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
@ 75 feet	Aug. 14	1,722*	1,660†		46†		304†	747*	696†			484*	480†		7·5*
102½—106 feet	Aug. 24	1,105	1,022		30		175	396	378			364	310		7·3
190—325 feet	Sept. 4	677	712		27		99	231	224			320	260		7·3
337—700 feet	Sept. 30	680	738		26	68*	114	231	221	3*		284	248		7·3

*Analysis by SRC Laboratory.
†Analysis by ICI Laboratory.

Exploratory boring, KH_1, located 5 furlongs east of Khamra. Destroyed.

	(1951)	Analyses (in parts per million)													
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
0—100 feet	June 26	282*	308†		32†	5*		27*		5*		140*	106†		7·5†
120—285 feet	July 17	843	904		66	80		287		11		340	310		7·5
315—420 feet	Aug. 2	1,100	1,116		30	89		415		10		380	380		7·5
315—510 feet	Aug. 10	1,770	1,924		19	295		730		Trace		484	460		7·5
315—700 feet	Aug. 17	2,457	2,552		19	572		927		Trace		740	660		7·5

**Analysis by SRO Laboratory.*
†Analysis by IOI Laboratory.

Exploratory boring, N_1, located 5 furlongs east of Nagalpur and 30 feet east of N_2. Destroyed.

	(1950)	Analyses (in parts per million)													
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
@ 85 feet	July 29	337*	312†				Trace†	32*				168*	140†		7·2†
@244 feet	Aug. 21	440			68†			94				292			
175—300 feet	Aug. 20	543	622		21		114	143				282	236		7·5

**Analysis by SROLaboratory.*
†Analysis by IOI Laboratory.

APPENDIX 5—*concld.*

Exploratory boring, N_2, located 5 furlongs east of Nagalpur. Destroyed.

	(1951)	Analyses (in parts per million)													
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
30—80 feet	Feb. 20	257*				15*		24*		6*		152*			
83—225 feet	Mar. 3	322	432†		132†	11		34		4		172	1247†		7·7†
360—520 feet	Apr. 14	765	762		96	32		204		8		260	260		7·6
360—700 feet	Apr. 24	673				33		207		7		264			

**Analyses in SRC Laboratory.*

†*Analyses in ICI Laboratory.*

APPENDIX 6.

Partial chemical analyses of waters from production tube wells in the Viri area, February 1951—May 1954.

(Analyses by Sindhu Resettlement Corporation Laboratory, Gandhidham.)

Tube well, A_3, located 1½ furlongs south of Viri.

Depth 220 feet. Infrequently used as of May 1954.

Date of Sampling	Total solids	Sulphate (SO_4)	Chloride (Cl)	Total hardness as $CaCO_3$	Remarks
	Analyses (in parts per million)				
(1)	(2)	(3)	(4)	(5)	(6)
Feb. 27, 1951 . .	902	67	240		Analysis in Geol. Surv. of India, Calcutta.
Oct. 16, 1953 . .	1,070	69	276	275	SIO_2, 98 ppm

Tube well, A_5, located 2 furlongs SW of Viri.

Depth 210 feet. Used intermittently as of May 1954.

(1)	(2)	(3)	(4)	(5)	(6)
Apr. 23, 1951 . .	838	40	211	184	
Nov. 11, 1951 . .	888	69	226	308	
Dec. 12, 1951 . .	862	49	214	392	
Oct. 16, 1953 . .	910	36	235	125	SIO_2, 84 ppm
Dec. 3, 1953 . .	904	58	232	285	SIO_2, 55 ppm
Jan. 16, 1954 . .	928	45	248	265	SIO_2, 19 ppm
Mar. 18, 1954 . .			248	293	SIO_2, 56 ppm
May 12, 1954 . .	975		230	175	SIO_2, 27 ppm

Tube well, A_6, located one and a half mile SW of Viri.

Depth 155 feet. Used as observation well.

(1)	(2)	(3)	(4)	(5)	(6)
Mar. 15, 1951 . .	764		83	60	0-90 feet
Mar. 16 . . .	782	22	83	60	0-120 feet
Mar. 21 . . .	918		85	52	at 155 feet
Mar. 24 . . .	985		201	240	155-200 feet
May 28, 1951 . .	874	23	203	190	Completed well
Dec. 25, 1953 . .	603		62	25	SIO_2, 71 ppm
Feb. 4, 1954 . .	563		61	50	SIO_2, 50 ppm

APPENDIX 6—*contd.*

Tube well, B_1, located one and a quarter mile WSW of Viri.
Depth 220 feet. Actively used as of May 1954.

(1)	(2)	(3)	(4)	(5)	(6)
May 17, 1951 . .	636	23	155	278	Completed well
Feb. 15, 1952 . .	702	30	173	280	
May 3 . . .	704	24	166	284	
May 17 . . .	707	39	170	247	
June 2 . . .	722	36	171	258	
July 8 . . .	736	31	173	250	
July 21 . . .	762	40	176	248	
Aug. 9 . . .	733	39	177	260	
Nov. 10 . . .	742	38	182	240	
Nov. 26, 1952 . .	754	48	184	250	
Feb. 9, 1953 . .	748	42	185	250	
Feb. 26 . . .	743	45	183	250	
April 4 . . .	754	44	188	235	
April 18 . . .	759	47	190	250	
May 21 . . .	761	46	187	245	
July 16 . . .	749	40	173	240	
Aug. 7 . . .	751	40	193	250	
Oct. 8 . . .	690	41	168	240	SiO_2, 54 ppm
Dec. 4, 1953 . .	723		172	285	SiO_2, 47 ppm
Jan. 15, 1954 . .	780	54	182	255	SiO_2, 20 ppm
Feb. 4 . . .	741		180	260	SiO_2, 32 ppm
Mar. 10, 1954 . .	753		172	210	SiO_2, 22 ppm

Tube well, B_3, located 3 furlongs west of Viri.
Depth 215 feet. Actively used as of May 1954.

(1)	(2)	(3)	(4)	(5)	(6)
March 18, 1951 . .	470	32	103	240	0-199 feet
May 3 . . .	172	18	92	220	Completed well
Dec. 4 . . .	488	17	96	265	
May 18, 1952 . .	486	21	94	214	
June 25 . . .	468	27	90	220	
July 5 . . .	472	19	88	207	
July 19 . . .	460	18	89	203	
Aug. 3 . . .	458	21	89	207	
Aug. 11 . . .	458	19	88	207	
Sept. 1 . . .	450	24	88	208	

APPENDIX 6—*concld.*

Tube well, B_3 located 3 furlongs west of Viri—contd.

(1)	(2)	(3)	(4)	(5)	(6)
Sept. 15, 1952 . .	457	18	88	203	
Sept. 29 . . .	450	20	88	203	
Oct. 8 . . .	452	19	88	201	
Oct. 20 . . .	472	20	90	210	
Nov. 11 . . .	466	20	90	210	
Nov. 25 . . .	463	20	86	210	
Dec. 7, 1952 . .	459	20	87	205	
Feb. 6, 1953 . .	451	20	86	205	
Feb. 28 . . .	474	21	89	205	
April 2 . . .	467	19	85	195	
Oct. 8, 1953 . .	469	24	87	230	SiO_2, 44 ppm
March 11, 1954 . .	451		83	150(?)	SiO_2, 15 ppm
March 18 . . .	463		84	205	SiO_2, 38 ppm
May 12, 1954 . .	521		78	170	SiO_2, 46 ppm

APPENDIX 7.

Results of periodic chemical analyses for chlorides in water samples from production tube wells in the Viri area, February 1951—May 1954.

(Analyses by Sindhu Resettlement Corporation, Gandhidham.)

(Chloride content, in parts per million.)

Tube well, A_3, located 1½ furlongs south of Viri.
Depth 220 feet.

Date of sampling	Chloride content	Date of sampling	Chloride content
February 27, 1951	240	August 27, 1953	290
May 31, 1951	278	Sept. 3	289
May 26, 1953	300	October 1	276
June 12	284	October 8	274
June 15	289	October 16, 1953	276
June 24	256	Feb. 11, 1954	272
June 30	278	Feb. 26	267
July 8	284	March 5	272
July 11	286	March 11	275
July 15	285	March 18	264
July 21	286	March 25	269
July 28	287	May 6	251
August 4	281	May 15	249
August 18	278	May 21 ,1954	289
August 21, 1953	285		

APPENDIX 7—*contd.*

Tube well, A_5, located 2 furlongs south-west of Viri.
Depth 210 feet.

Date of sampling	Chloride content	Date of sampling	Chloride content
April 23, 1951	211	November 27, 1953	270(?)
May 31, 1951	218	December 11	238
June 15, 1953	240	December 17	243
July 11	236	December 24, 1953	246
July 15	230	January 1, 1954	240
July 21	240	January 21	258
July 28	233	January 29	238
August 4	238	February 11	244
August 14	238	February 26	246
August 21	234	March 5	237
August 28	240	March 11	238
September 3	235	March 25	238
October 1	238	May 6	230
October 8	229	May 15	234
October 16	235	May 21, 1954	250
October 23, 1953	233		

Tube well, A_6, located one and a half mile south-west of Viri.
Depth 155 feet.

Date of sampling	Chloride content	Date of sampling	Chloride content
December 18, 1953	72	February 11, 1954	61
December 24, 1953	61	February 19	60
January 22, 1954	59	February 26	62
January 29, 1954	64	March 5	60
		March 11, 1954	59

APPENDIX 7—*contd.*

Tube well, B_1, located one-quarter mile west-southwest of Viri. Depth 220 feet.

Date of sampling	Chloride content	Date of sampling	Chloride content
May 17, 1951	155	July 28, 1953	177
May 8, 1952	166	August 7	193
May 17	170	August 13	171
June 2	171	August 21	185
July 8	173	September 4	185
July 21	176	October 2	181
Agust 9	177	October 15	168
November 10	182	October 16	181
November	184	October 23	178
February 9, 1953	185	October 30	182
February 26	183	November 6	168
April 4	188	November 27	165
April 18	190	December 11	187
May 21	187	December 17	178
May 26	189	December 24, 1953	185
June 12	190	January 1, 1954	166
June 15	192	January 21	162
June 24	180	January 29	186
June 30	184	February 11	171
July 10	185	February 26	178
July 15	182	March 5	175
July 16	183	March 18	183
July 21	190	March 25	169

APPENDIX 7—*contd.*

Tube well, B_3, located 3 furlongs west of Viri.
Depth 215 feet.

Date of sampling	Chloride content	Date of sampling	Chloride content
May 3, 1951	94	June 19, 1953	87
May 18, 1952	94	July 1	86
June 25	90	July 8	85
July 5	88	July 15	88
July 19	89	July 21	85
August 3	89	August 5	89
August 11	88	August 13	91
September 1	88	August 22	83
September 15	88	September 3, 1953	89
September 29	88	October 1	82
October 8	88	October 8	87
October 20	90	October 16	82
November 11	90	October 23	83
November 25	86	October 29	82
December 7, 1952	87	November 5	85
February 6, 1953	86	November 26,	81
February 28	89	February 18, 1954	85
April 2	85	May 6	77
May 26	84	May 15	77
June 11, 1953	83	May 21, 1954	93

APPENDIX 8.

Logs of deep exploratory borings in the Anjar-Khedoi region. (All borings put down by John Mowlems Co., Ltd. Formation descriptions and stratigraphic correlations by the writers.)

Exploratory boring, A_2. Land surface altitude 207 feet. Started February 28, 1951 and completed March 10, 1951. Located 3 furlongs southeast of Viri and 975 feet southeast of tube well A3 at 23°04′38″ N and 70°00′44″E. Destroyed because water found to be brackish.

	Formation	Thickness (feet)	Depth (feet)
	Upper Bhuj series :—		
(A)	Clay, sandy, brown	5	5
(B)	Siltstone clayey and fine sandy, white, feldspathic	10	15
(C)	Sandstone, medium to fine, argillaceous .	30	45
(D)	Sandstone, silty, yellowish brown . .	15	60
(E)	Sandstone, medium, soft, argillaceous, yellowish brown ; water-bearing	25	85
(F)	Sandstone, medium, soft, yellowish brown ; water-bearing	30	115
(G)	Sandstone, very coarse and conglomeratic, soft, pale gray with small pebbles of quartz and feldspar ; water-bearing	10	125
(H)	Sand stones, medium to coarse, soft subrounded grains of quartz predominant with some kaolinized feldspar ; water-bearing	10	135
(I)	Sandstone, medium, soft, argillaceous, feldspathic	10	145
(J)	Sandstone, very coarse, soft subrounded grains, pale gray ; water-bearing	5	150
(K)	Sandstone, medium to coarse, soft, sub-rounded grains, pale yellowish gray ; water-bearing	25	175
(L)	Shale, silty and fine sandy, white, feldspathic .	10	185
(M)	Siltstone, white	10	195
(N)	Sandstone, medium to fine, soft argillaceous, feldspathic	10	205
(O)	Shale, whitish purple, compact . . .	1	206
			T.D.

APPENDIX 8—*contd.*

Exploratory boring, A3. Land-surface altitude 208 feet. Started July 26, 1950 and completed March 9, 1951. Located one and a half furlongs south of Viri at 23°03′45″ N. and 70°00′30″ E. Finished as production tube well A3 with depth 220 feet.

	Formation	Thickness (feet)	Depth (feet)
	Alluvium :—		
(A)	Soil, sandy, black with calcium carbonate nodules	11	11
(B)	Sand, coarse with trap and quartz pebbles .	4	15
	Upper Bhuj series (at base of Deccan trap) :—		
(C)	Sandstone, medium to coarse, soft, subrounded grains, pale gray ; quartz predominant with some kaolinized feldspar ; water-bearing.	90	105
(D)	Sandstone, medium, soft, argillaceous, white to pale gray.	20	125
(E)	Sandstone, like (C) ; water bearing . .	30	155
(F)	Sandstone, like (D)	20	175
(G)	Sandstone, like (C) ; water-bearing . .	43	218
(H)	Sandstone, fine, soft, argillaceous, white to pale gray.	22	230
(I)	Sandstone, medium to coarse, soft, subrounded grains, pale gray, quartz predominant with some kaolinized feldspar ; water-bearing.	20	250
(J)	Sandstone, medium soft, silty, white to pale gray.	75	325
(K)	Sandstone, medium to coarse, soft argillaceous, pale gray.	75	400
(L)	Shale, silty and sandy, compact, pink to dark gray colour.	30	430
(M)	Sandstone, medium to fine, soft, silty and clayey.	80	510
(N)	Sandstone, medium to coarse, soft, pale gray to white, subrounded grains of quartz predominant with some kaolinized feldspar ; water-bearing.	325	835
(O)	Shale, clay, compact, blue-gray . . .	15	850 T.D

APPENDIX 8—*contd.*

Exploratory boring, AA5. Land-surface altitude 215 feet. Started August 8, 1950 and completed October 6, 1950. Located ¼ mile southwest of Viri at 23°04′47″ N. and 70°00′18″ E. Destroyed due to collapse of hole.

	Formation	Thickness (feet)	Depth (feet)
	Alluvium :		
(A)	Sand, black with calcium carbonate nodules .	12	12
	Upper Bhuj series :		
(B)	Sandstone, argillaceous, medium to fine, intercalated with thin gray and brown shales.	38	50
(C)	Sandstone, medium to coarse, somewhat argillaceous, soft, subrounded quartz grains predominant pale gray ; water-bearing.	80	130
(D)	Sandstone, argillaceous, medium to fine, soft, white ; water-bearing.	25	155
(E)	Sandstone, like (C) ; water-bearing . .	40	195 T.D.

Exploratory boring, BH1. Land-surface altitude 277 feet. Started August 31, 1951 and completed December 31, 1951. Located 1 5/8 miles southeast of Bhadroi at 23°07′32″ N. and 69°58′00″ E. Destroyed.

	Formation	Thickness (feet)	Depth (feet)
	Alluvium :		
(A)	Sand, brown	10	10
	Upper Bhuj series :		
(B)	Shale, hard, white to reddish brown with circular iron stains along cross-bedding, non-calcareous.	4	14
(C)	Sandstone, medium to fine, argillaceous, compact, white.	11	25
(D)	Sandstone, medium, somewhat argillaceous, compact, white to light brown.	5	30
(E)	Sandstone, medium, siliceous and ferruginous cement, very hard, brownish black.	1	31
(F)	Shale, clay, dark grey, slightly arenaceous between 35 and 43 feet.	18	49
(G)	Sandstone, like (E)	1	50
(H)	Sandstone, medium, argillaceous and ferruginous, yellowish brown, cross-bedded with tiny clay balls.	10	60
(I)	Shale clay, pale gray, compact, in part micaceous.	10	70

APPENDIX 8—*contd.*

Exploratory boring, BH1—*contd.*

	Formation	Thickness (feet)	Depth (feet)
(J)	Sandstone, fine to medium, soft, pale brown .	5	75
(K)	Shale, sandy, micaceous with streaks of coal (lignite ?), dark gray.	4	79
(L)	Sandstone, medium, ferruginous with alternating hard and soft bands, brownish black to pale brown.	6	85
(M)	Sandstone, medium, argillaceous, white to pale brown, compact, crossbedded.	4	89
(N)	Shale, reddish brown to white, compact becomes sandy at bottom.	6	95
(O)	Sandstone, medium to coarse, soft, sub-angular to subrounded grains of quartz predominant with some kaolinized feldspar, also some $\frac{1}{8}$—$\frac{1}{4}$ inch pebbles of white quartz, pale gray; water-bearing.	160	255
(P)	Shale, sandy, white, compact, with yellow to reddish brown ferruginous streaks.	5	260
(Q)	Shale, sandy, compact, dark to light gray .	7	267
(R)	Siltstone, sandy, compact, pale gray to white	13	280
(S)	Sandstone, like (O); water-bearing . .	105	385
	Lower Bhuj series:		
(T)	Sandstone, ferruginous, very hard . .	1	386
(U)	Shale, purple to light gray, compact . .	4	390
(V)	Shale, carbonaceous, dark to pale gray, sandy in upper part.	10	400
(W)	Shale, massive, compact, dark gray . .	10	410
(X)	Sandstone, fine to coarse, soft, pale brownish gray, subangular grains of quartz predominant with some kaolinized feldspar; water-bearing.	35	445
(Y)	Sandstone, fine, micaceous, compact, with yellow to brown iron stains.	4	449
(Z)	Sandstone, medium to coarse, compact, somewhat ferruginous, yellowish brown to white.	6	455
(AA)	Shale, carbonaceous, dark gray to black with thin one mm. laminae of coal (lignite ?).	4	459
(BB)	Coal, (lignite ?)	1	460

APPENDIX 8—*contd.*

Exploratory boring, BH 1—*contd.*

	Formation	Thickness (feet)	Depth (feet)
	Siltstone, sandy micaceous, laminated, finely cross bedded, brownish yellow, with streaks of granular marcasite (?) at 462 feet.	10	470
	Lower Bhuj series (continued) :		
(CC)	Sandstone, medium to coarse, soft like (X); water-bearing (?)	15	485
(DD)	Shale, sandy, carbonaceous, laminated, compact, dark gray with one m.m. streaks of coal.	4	489
(EE)	Sandstone, fine to coarse like (X); water-bearing (?)	6	495
(FF)	Shale, massive, somewhat micaceous, with a few streaks of coal, dark gray.	4	499
(GG)	Sandstone, medium, soft, like (X); water bearing (?).	11	510
(HH)	Shale, sandy, micaceous, gray . . .	5	515
(II)	Shale, laminated, micaceous with carbonaceous streaks, gray, alternating with 3—4 inch bands of fine to medium compact sandstone.	20	535
(JJ)	Shale, carbonaceous, dark gray . . .	4	539
(KK)	Coal, (lignite ?)	2	541
(LL)	Shale, carbonaceous, dark gray . . .	1	542
(MM)	Coal, (lignite ?) with leaf impressions . .	½	542½
(NN)	Shale, carbonaceous, dark gray . . .	1½	544
(OO)	Sandstone, medium to coarse, soft, like (X) .	6	550
(PP)	Shale, sandy, laminated, gray with occasional carbonaceous streaks alternating with 1—3 inch bands of fine to medium compact sandstone.	40	590
(QQ)	Sandstone, medium to fine, soft, pale gray, like (X); water-bearing (?)	20	610
(RR)	Shale, sandy, micaceous, compact dark gray .	5	615
(SS)	Sandstone, medium to coarse, soft, pale gray, like (X).	10	625
(TT)	Shale, sandy, micaceous, carbonaceous, laminated, gray.	9	634
(UU)	Sandstone, fine, micaceous, compact, pale gray	11	645
(VV)	Shale, sandy, laminated, carbonaceous with thin streaks of fine sandstone.	25	670
(WW)	Sandstone, silty, medium to fine soft . .	5	675
(XX)	Shale, like (VV)	25	700
			T.D.

APPENDIX 8—*contd.*

Exploratory boring, K2. Land-surface altitude 257 feet. Started June 23, 1950 and completed August 1, 1950. Located one furlong NNW of Khedoi Mota at 23°03′30″ N. and 69°55′00″ E. Destroyed.

	Formation	Thickness (feet)	Depth (feet)
(A)	Soil	1	1
	Upper Bhuj series :		
(B)	Sandstone, medium to coarse, somewhat argillaceous, soft, subangular to subrounded grains of quartz predominant with some kaolinized feldspar, white to pale yellow; water-bearing.	54	55
(C)	Shale, sandy, micaceous, variegated, compact to hard.	12	60
(D)	Sandstone, fine to medium, soft, white . .	5	65
(E)	Shale, sandy, like (C)	2	67
(F)	Sandstone, medium to fine, argillaceous, micaceous, compact with brown ferruginous bands.	13	80
(G)	Sandstone, medium to coarse, compact ferruginous, reddish, yellow.	25	105
(H)	Sandstone, medium to coarse, soft, subangular quartz grains predominant with some kaolinized feldspar, white; water-bearing.	65	170
(I)	Shale, micaceous, brown, compact . .	5	175
(J)	Sandstone, coarse to medium, soft . .	5	180
(K)	Shale, variegated, compact, becomes sandy near bottom.	10	190
(L)	Sandstone, fine to medium, soft argillaceous, white; water-bearing.	30	220
(M)	Shale, sandy, micaceous, compact . .	5	225
(N)	Sandstone, fine to coarse, soft argillaceous near bottom.	13	238
(O)	Shale, micaceous, compact	2	240
(P)	Sandstone, medium to coarse, soft, subangular quartz grains predominant with some kaolinized feldspar, white to pale reddish yellow; water-bearing.	86	326
(Q)	Shale, micaceous, compact, white sandy near bottom.	4	330
(R)	Sandstone, medium to coarse, somewhat argillaceous and ferruginous, white to pale reddish yellow like (P); water-bearing.	46	376
(S)	Shale, compact, brown to pale gray, ferruginous and sandy near bottom.	15	391
(T)	Sandstone, fine to medium, micaceous, argillaceous, compact, with ferruginous streaks, pale yellow.	9	400

APPENDIX 8—*contd.*

Exploratory boring, K2—*contd.*

	Formation	Thickness (feet)	Depth (feet)
	Upper Bhuj series—*contd.*		
(U)	Sandstone, medium to coarse, soft, subangular quartz grains predominant with some kaolinized feldspar, some small quartz pebbles between 455—460 feet, white to pale gray; water-bearing.	70	470
(V)	Shale, compact, white to brown, somewhat sandy near bottom.	5	475
(W)	Sandstone, fine to coarse, soft argillaceous, pale yellow.	5	480
(X)	Shale, compact, white	3	483
(Y)	Sandstone, coarse to medium, soft, slightly argillaceous in part, subangular quartz grains with some kaolinized feldspar, pale gray; water-bearing.	160	643
(Z)	Shale, compact, grayish blue . . .	7	650
(AA)	Sandstone, medium to very coarse, soft, subangular quartz grains predominant with some kaolinized feldspar, white to pale gray; water-bearing.	55	705 T. D.

Exploratory boring, KH1. Land-surface altitude 273 feet. Started May 1, 1951 and completed August 30, 1951. Located 5 furlongs east of Khamra at 23°06′15″ N. and 69°51′02″ E. Destroyed.

	Formation	Thickness (feet)	Depth (feet)
	Alluvium :		
(A)	Sand, fine to medium, subangular, white to brown.	15	15
(B)	Sand with gravel; subrounded quartz and basalt pebbles.	5	20
	Upper Bhuj series :		
(C)	Sandstone, medium to fine, soft, subangular grains, pale yellowish gray to white; quartz predominant with some kaoline; water-bearing.	45	65
(D)	Sandstone, coarse to very coarse, soft, subangular grains, pale yellowish gray with streaks of fine subrounded quartz conglomerate; water-bearing.	55	120
(E)	Sandstone, coarse, gritty, soft subangular grains, white to pale yellowish gray; quartz predominant with some kaolinized feldspar; water-bearing.	55	175
(F)	Sandstone, coarse to medium, soft, subangular grains, pale gray to white; quartz predominant with some kaolinized feldspar; water-bearing.	110	285
(G)	Sandstone, fine, laminated, compact, micaceous and feldspathic, brownish yellow to white; laminae cemented by iron oxides alternate with silica cemented laminae, 1—2 mm. wide.	5	290

APPENDIX 8—*contd.*

Exploratory boring, KH1—*contd.*

	Formation	Thickness (feet)	Depth (feet)
	Upper Bhuj series—*contd.*		
(H)	Sandstone, medium to coarse, soft, pale brownish gray, subrounded grains of quartz predominant with some kaolinized feldspar; water-bearing.	10	300
(I)	Sandstone, fine, compact, micaceous and feldspathic, yellowish-brown with thin stringers and galls of clay.	5	305
(J)	Shale, fine, sandy, dark gray with ½ to 1 mm. laminae of coal (lignite ?)	8	313
(K)	Sandstone, like (H); water-bearing . .	74	387
	Lower Bhuj series :		
(L)	Shale, massive, compact, dark gray with thin sandy streaks.	3	390
(M)	Sandstone, like (H); water-bearing . .	10	400
(N)	Shale, laminated, carbonaceous, dark gray to black with thin laminae of coal about one mm. thick, also thin sandy streaks.	10	410
(O)	Sandstone, like (H); water-bearing (?) . .	10	420
(P)	Shale, compact, carbonaceous, dark gray with thin streaks of coal up to 5 mm. thick.	5	425
(Q)	Sandstone, medium to coarse, soft, pale gray, subangular to subrounded grains of quartz predominant with some kaolinized feldspar; water-bearing.	20	445
(R)	Sandstone, fine to medium, compact, carbonaceous, micaceous and feldspathic.	5	450
(S)	Sandstone, medium, soft with streaks of fine quartz conglomerate; water-bearing.	15	465
(T)	Shale, laminated, compact, dark gray, micaceous with thin streaks of coal about one mm. thick.	5	470
(U)	Sandstone, medium to coarse, soft, pale gray; quartz predominant with some kaolinized feldspar and streaks of fine quartz conglomerate; water-bearing.	22	492
(V)	Shale, laminated, compact, dark gray, micaceous and carbonaceous with thin sandy streaks.	8	500
(W)	Sandstone, like (Q)	5	505
(X)	Shale, like (T)	3	508
(Y)	Sandstone, medium, compact, micaceous and feldspathic.	2	510
(Z)	Shale, like (V)	10	520
(AA)	Sandstone, like (U)	10	530
(BB)	Shale, like (V)	10	540
(CC)	Sandstone, like (U); water-bearing . .	65	605
(DD)	Shale, laminated, compact, dark gray, with 50 mm. seam of coal (lignite ?) at base.	1	606
(EE)	Sandstone, medium, compact, micaceous and feldspathic.	9	615
(FF)	Sandstone, medium to coarse, soft, pale gray; quartz predominant with some kaolinized feldspar and streaks of fine quartz conglomerate; water-bearing.	85	700 T. D

APPENDIX 8—*contd.*

Exploratory boring, N1. Land-surface altitude 237 feet. Started July 22, 1950 and completed October 3, 1950. Located 5 furlongs east of Nagalpur and 30 feet east of N2 at 23°05′30″ N. and 70°00′00″ E. Destroyed.

	Formation	Thickness (feet)	Depth (feet)
(A)	Soil, sandy with quartz grains . . .	5	5
	Upper Bhuj series :		
(B)	Sandstone, fine, argillaceous, compact, grey to white.	48	53
(C)	Sandstone, medium to coarse, soft, subangular grains of quartz predominant with some kaolinized feldspar, pale gray ; water-bearing.	61	114
(D)	Sandstone, medium to fine, argillaceous compact, white.	3	117
(E)	Sandstone, coarse, like (C) ; water-bearing .	19	136
(F)	Sandstone, medium, argillaceous, white, soft ; water-bearing (?).	21	157
(G)	Sandstone, coarse, like (C) ; water-bearing .	15	172
(H)	Sandstone, medium to coarse, argillaceous, white, soft ; water-bearing.	89	261
(I)	Shale, white, compact, somewhat sandy in part.	7	268
(J)	Shale, medium to fine sandy, white, compact	13	281
(K)	Sandstone, medium to coarse, soft, subangular grains of quartz predominant with some kaolinized feldspar, pale yellowish gray ; water-bearing.	29	300
			T.D.

Exploratory boring, N2. Land-surface altitude 237 feet. Started January 1, 1951 and completed April 26, 1951. Located 5 furlongs east of Nagalpur at 23°05′30″ N. and 70°03′00″ E. Destroyed.

	Formation	Thickness (feet)	Depth (feet)
(A)	Soil, sandy, gray	10	10
(B)	Sand, wind-blown, fine	5	15
	Upper Bhuj series ;		
(C)	Sandstone, fine to medium, argillaceous compact, gray to white.	45	60
(D)	Sandstone, medium to coarse, soft, subangular grains of quartz predominant with some kaolinized feldspar, also some $\frac{1}{8}$ — $\frac{1}{4}$ inch quartz pebbles, pale gray ; water-bearing.	30	80

APPENDIX 8—*concld.*

Exploratory boring, N2—*contd.*

	Formation	Thickness (feet)	Depth. (feet)
(E)	Shale, micaceous, compact . . .	3	83
(F)	Sandstone, like (D) ; water-bearing .	62	145
(G)	Sandstone, fine to medium, soft, somewhat argillaceous, subangular grains of quartz predominant with some kaolinized feldspar, pale brownish gray ; water-bearing.	25	170
(H)	Sandstone, very coarse to conglomeratic, soft, like (D) ; water-bearing.	5	175
(I)	Sandstone, like (G) ; water-bearing . .	10	185
(J)	Sandstone, very coarse to conglomeratic, soft, like (D) ; water-bearing.	20	205
(K)	Sandstone, medium to coarse, soft, subangular grains of quartz predominant with some kaolinized feldspar, pale brown to gray ; water-bearing.	100	305
(L)	Shale, pink, compact	15	320
(M)	Sandstone, medium to coarse, soft, subangular grains of quartz predominant with some kaolinized feldspar, also some ⅛ — ¼ inch quartz pebbles, pale gray ; water-bearing.	20	340
(N)	Shale, pink, compact	9	349
(O)	Sandstone, ferruginous and siliceous cement, very hard, dark brown.	1	350
(P)	Coal (lignite ?)	⅓	350⅓
(Q)	Shale, compact, dark gray with thin streaks of coal containing plant impressions.	9⅔	360
(R)	Sandstone, medium to coarse, soft, pale gray, like (M) ; water-bearing.	160	520
(S)	Sandstone, medium to fine, soft, argillaceous, pale gray with thin intercalations of brown shale.	15	535
(T)	Sandstone, medium to coarse, soft, subangular grains of quartz predominant with some kaolinized feldspar, also some ⅛ — ¼ inch quartz pebbles, pale gray ; water-bearing.	165	700 T.D.

APPENDIX 9.

Logs of production tube wells in the Viri area. (All borings put down by Johns Mowlems Co., Ltd. Formation descriptions and stratigraphic correlations by the writers.)

Note :—See Appendix 8 for logs of exploratory borings, A_2 and AA_5 and production tube well, A_3 in the Viri area.

Production tube well, A_5. Land-surface altitude 215 feet. Started October 31, 1950 and completed April 24, 1951. Located ¼ mile southwest of Viri at 23°04′47″ N. and 70°00′18″ E. Well completed at a depth of 210 feet.

	Formation	Thickness (feet)	Depth (feet)
	Alluvium :		
(A)	Sand with calcium carbonate nodules	12	12
	Upper Bhuj series :		
(B)	Sandstone, argillaceous, fine, soft, white	28	40
(C)	Sandstone, medium to coarse, somewhat argillaceous, soft, subrounded quartz grains predominant, pale gray ; water-bearing.	84	124
(D)	Shale, pale violet colour, compact	6	130
(E)	Sandstone, medium to fine, argillaceous, soft, white.	10	140
(F)	Shale, white, compact	10	150
(G)	Sandstone, like (G) ; water-bearing	35	185
(H)	Shale, white, compact, somewhat arenaceous near base.	25	210
			T.D.

Production tube well, A_6. Land-surface altitude 217 feet. Started March 14, 1951 and completed May 31, 1951. Located ½ mile SW of Viri at 23°05′37″ N. and 70°00′06″ E. Well completed at a depth of 155 feet.

	Formation	Thickness (feet)	Depth (feet)
	Alluvium :		
(A)	Sand, brown with trap pebbles	10	10
	Upper Bhuj series :		
(B)	Sandstone, medium, argillaceous pale yellow, soft.	10	20
(C)	Sandstone, medium to coarse, pale gray, with small subangular quartz pebbles somewhat argillaceous near base ; water-bearing.	40	60
(D)	Shale, silty, white to pale brown	5	65
(E)	Siltstone, fine sandy, pale yellow, soft, somewhat more arenaceous near base.	15	80
(F)	Sandstone, coarse, hard, yellow with siliceous-ferruginous cement.	1	81
(G)	Shale, purplish gray to white, compact	14	95

APPENDIX 9—*contd.*

Production tube well A_6—*contd.*

	Formation	Thickness (feet)	Depth (feet)
	Uper Bhuj series—*contd.*		
(H)	Shale, silty white, soft, somewhat micaceous between 110-115 feet.	20	115
(I)	Sandstone, medium to coarse, soft, subrounded grains, quartz predominant with some kaolinized feldspar ; water-bearing.	40	155
(J)	Shale, purplish gray, white . . .	5	160
(K)	Shale, silty, pale gray	15	175
(L)	Sandstone, argillaceous, white, micaceous	25	200
(M)	Shale, brown, compact	5	205
			T.D.

Production tube well, B_1. Land-surface altitude 221 feet. Started February 2, 1951 and completed May 17, 1951. Located ¼ mile WSW of Viri at 23°04′50″ N. and 70°00′08″ E. Well completed at a depth of 220 feet.

	Formation	Thickness (feet)	Depth (feet)
	Alluvium :		
(A)	Sand	15	15
	Upper Bhuj series :		
(B)	Sandstone, medium to fine, somewhat argillaceous, soft, subangular quartz grains predominant, pale yellow.	15	30
(C)	Sandstone, coarse and conglomeratic, soft, pale gray with ⅓—¼ in. subangular pebbles of quartz and some feldspar ; water-bearing.	11	41
(D)	Siltstone, fine sandy, soft, pale yellow .	7	48
(E)	Sandstone, medium to coarse, somewhat-argillaceous, soft, subrounded quartz grains predominant pale gray ; water-bearing.	32	80
(F)	Sandstone, like (C) ; water bearing . .	10	90
(G)	Sandstone, like (E) ; water-bearing . .	15	105

APPENDIX 9—*contd.*

Production tube well B1—*contd.*

	Formation	Thickness (feet)	Depth (feet)
	Upper Bhuj series—*contd.*		
(H)	Shale, pale violet to white, soft, plastic when wet.	30	135
(I)	Sandstone, medium to fine, argillaceous white to pale yellow, soft.	40	175
(J)	Sandstone, like (E) ; water-bearing . .	55	230
(K)	Shale, fine sandy, pale yellow . . .	5	235

Production tube well, B_3. Land-surface altitude 229 feet. Started February 15, 1951 and completed May 3, 1951. Located 3 furlongs west of Viri at 23°04′58″ N. and 70°00′03″ E. Well completed at a depth of 215 feet.

	Formation	Thickness (feet)	Depth (feet)
	Alluvium :		
(A)	Sand, brown	5	5
(B)	Silt, sandy with quartz pebbles . . .	5	10
	Upper Bhuj series :		
(C)	Sandstone, medium to fine, argillaceous, soft, white.	25	35
(D)	Siltstone, soft, white	5	40
(E)	Sandstone, medium coarse, somewhat argillaceous, soft subrounded quartz grains predominant, pale gray ; water-bearing.	70	110
(F)	Shale, pale gray, compact	10	120
(G)	Shale, fine sandy, compact . . .	7	127
(H)	Sandstone, medium, somewhat argillaceous soft, subrounded quartz grains predominant, pale gray to yellowish brown ; water-bearing.	43	170
(I)	Siltstone, fine sandy, soft, white . .	5	175
(J)	Sandstone, like (E) ; water-bearing . .	35	210
(K)	Shale, fine sandy, white, compact . .	5	215

APPENDIX 10.

Mechanical analyses of formation samples from deep exploratory borings and production tube wells in the Anjar-Khedoi region.

Well A_2, depth 206 feet. Located 3 furlongs SE of Viri. Samples from percussion drill bailer.

Sample No.	Depth of sample below land surface (feet)	Per cent of total by weight					Effective size of grain [1] (milli-meters)	Uniformity co-efficient [2]	Field classification of sample
		Silt and clay less than 0·06 mm	Fine sand 0·06 to 0·20 mm	Medium sand 0·20 to 0·60 mm	Coarse sand 0·60 to 2·0 mm	Gravel greater than 2·0 mm			
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
1	15	46	38	7	2	7	<·06	>2·17	Siltstone, clayey and fine sandy
2	40—45	17	17	54	11	1	<·06	>5·33	Sandstone, medium to fine, argillaceous
3	75—80	7	16	50	25	2	0·11	4·09	Sandstone, medium to coarse, argillaceous
4	105—110	5	9	61	23	2	0·15	3·07	Sandstone, medium to coarse, argillaceous
5	115—120	2	2	20	45	31	0·34	5·00	Sandstone, coarse, conglomeratic
6	135—140	18	20	41	20	1	<·06	>6·17	Sandstone, medium, argillaceous
7	160—165	9	8	48	33	2	0·09	6·11	Sandstone, medium to coarse
8	175—180	65	29	4	2	0	·06	>1·00	Shale, silty and fine sandy
9	195—200	12	18	60	9	1	<·06	>5·33	Sandstone, medium to fine, argillaceous
10	205—206	76	8	9	4	3	<·06	>1·00	Shale, clayey

See footnotes at end of appendix.

APPENDIX 10—*contd.*

Well A_3, depth 850 feet. Located 1 furlong S, of Viri. Samples from percussion drill bailer.

Sample No.	Depth of sample below land surface (feet)	Per cent of total by weight: Silt and clay less than 0·06 mm	Fine sand 0·06 to 0·20 mm	Medium sand 0·20 to 0·60 mm	Coarse sand 0·60 to 2·0 mm	Gravel greater than 2·0 mm	Effective size of grain [1] (millimeters)	Uniformity co-efficient [2]	Field classification of sample
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
1	20	6	8	49	35	2	0·10	5·70	Sandstone, medium to coarse
2	40	15	20	57	7	1	<0·60	>4·83	Sandstone, medium to coarse, argillaceous
3	57	4	5	35	51	5	0·24	3·41	Sandstone, coarse to medium
4	75	0	2	74	23	1	0·32	1·72	Sandstone, medium to coarse
5	80	4	10	68	18	0	0·16	1·81	do.
6	85	3	5	41	45	6	0·22	4·18	do.
7	90	2	6	45	43	4	0·23	3·17	do.
8	95	10	11	58	20	1	<0·06	>7·00	Sandstone, medium to coarse, argillaceous
9	110	20	18	44	16	2	<0·06	>5·66	do.
10	115	28	20	31	18	3	0·06	5·00	do.
11	140	7	12	50	29	2	0·16	3·00	Sandstone, medium to coarse
12	150	5	11	49	33	2	0·14	3·99	do.
13	156	11	22	45	20	2	<0·06	>6·50	Sandstone, medium to coarse, argillaceous
14	170	15	14	50	19	2	<0·06	>6·16	do.
15	180	2	7	40	44	7	0·21	4·00	Sandstone, medium to coarse
16	182	5	9	49	34	3	0·16	2·16	do.
17	190	5	10	71	12	2	0·12	3·83	do.

18	195	4	6	62	37	1	0·20	2·45	Sandstone, medium to coarse
19	201	3	4	13	62	18	0·29	4·14	do.
20	205	3	12	55	28	2	0·15	3·40	do.
21	210	2	10	56	29	3	0·19	2·90	do.
22	218	14	13	48	24	1	<0·06	>7·50	Sandstone, medium to coarse, argillaceous
23	230	8	6	48	36	1	0·01	5·90	Sandstone, medium to coarse,
24	245	2	6	56	34	2	0·28	2·47	do.
25	250	11	13	55	20	1	0·06	7·38	Sandstone, medium to coarse, argillaceous
26	290	20	12	46	14	8	<0·06	>6·50	do.
27	320	18	16	53	12	1	<0·06	>5·83	Sandstone, medium to fine, argillaceous
28	345	21	14	43	21	1	<0·06	>6·50	Sandstone, medium to coarse, argillaceous
29	375	20	12	53	14	1	<0·06	>5·83	do.
30	400	35	16	42	6	1	<0·06	>4·33	Shale, silty and fine sandy, argillaceous
31	425	30	17	39	11	3	<0·06	>4·83	do.
	450	27	16	39	17	1	<0·06	>5·55	Sandstone, medium, argillaceous
33	460	23	16	50	10	1	<0·06	>4·83	Sandstone, medium fine, argillaceous
34	500	20	18	56	5	1	<0·06	>5·83	do.
35	515	9	8	43	37	3	0·09	6·55	Sandstone, medium to coarse
36	540	2	4	44	47	3	0·24	3·08	do.
37	670	1	3	40	44	6	0·30	2·46	do.
38	735	1	4	51	41	3	0·26	2·50	do.
39	740	3	4	52	30	2	0·23	2·65	do.

See footnote atd en of appendix.

APPENDIX 10—*contd.*

Well A_5, depth 210 feet. Located 2 furlongs SW of Viri. Samples from percussion drill bailer.

Sample No.	Depth of sample below land surface (feet)	Per cent of total by weight					Effective size of grain[1] (milli-meters)	Uniformity co-efficient[2]	Field classification of sample
		Silt and clay less than 0·06 mm	Fine sand 0·06 to 0·20 mm	Medium sand 0·20 to 0·60 mm	Coarse sand 0·60 to 2·0 mm	Gravel greater than 2·0 mm			
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
1	12—15	27	20	39	10	4	<0·06	>4·10	Sandstone, fine to medium, silty
2	30—35	15	11	49	19	6	<0·06	>6·66	Sandstone, medium to coarse, silty
3	50—55	4	10	39	36	11	0·18	4·18	Sandstone, medium to coarse
4	70—75	2	6	41	48	3	0·23	3·39	do.
5	75—80	4	12	53	24	7	0·15	3·20	do.
6	100—105	21	19	42	14	4	<0·06	>4·66	Sandstone, medium to fine, silty
7	115—120	1	5	29	59	6	0·27	3·07	Sandstone, medium to coarse
8	160—165	11	16	62	10	1	0·15	2·33	Sandstone, medium to fine
9	185—190	4	6	18	63	9	0·20	6·00	Sandstone, coarse to medium
10	195—200	5	11	32	43	9	0·15	6·00	do.

See footnotes at end of appendix.

APPENDIX 10—*contd.*

Well AA_5, depth 195 feet. Located 2 furlongs SW of Viri. Samples from percussion drill bailer.

Sample No.	Depth of sample below land surface (feet)	Silt and clay less than 0·06 mm	Per cent of total by weight Fine sand 0·06 to 0·20 mm	Medium sand 0·20 to 0·60 mm	Coarse sand 0·60 to 2·0 mm	Gravel greater than 2·0 mm	Effective size of grain [1] (millimeters)	Uniformity co-efficient [2]	Field classification of sample
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
1	20	26	21	38	10	5	<0·06	>4·88	Sandstone, medium to fine, silty
2	50	10	11	48	25	6	0·06	8·16	Sandstone, medium to coarse
3	70	3	7	48	38	4	0·20	3·10	do.
4	95	1	5	27	61	6	0·27	3·26	Sandstone, coarse to medium
5	124	84	3	7	5	1	<0·06	>1·00	Shale
6	135	9	8	42	37	4	0·07	8·57	Sandstone, medium to coarse
7	145	80	6	8	6	0	<0·06	>1·00	Shale
8	150	9	15	50	23	3	0·09	4·89	Sandstone, medium to coarse
9	175	3	7	53	36	1	0·20	2·90	do.
10	200	28	9	35	25	3	<0·06	>6·83	do.

See footnotes at end of appendix.

APPENDIX 10—*contd.*

Well A_6, depth 205 feet. Located one-half mile SW of Viri. Samples from percussion drill bailer.

Sample No.	Depth of sample below land surface (feet)	Per cent of total by weight					Effective size of grain [1] (millimeters)	Uniformity co-efficient [2]	Field classification of sample
		Silt and clay less than 0·06 mm	Fine sand 0·06 to 0·20 mm	Medium sand 0·20 to 0·60 mm	Coarse sand 0·60 to 2·0 mm	Gravel greater than 2·0 mm			
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
1	15—20	20	16	35	23	6	<0·06	>7·00	Sandstone, medium to coarse, silty
2	25—30	5	8	36	49	2	0·17	4·70	Sandstone, coarse to medium
3	55—60	11	13	26	42	8	<0·06	>13·66	Sandstone, coarse to medium, silty
4	60—65	56	26	4	11	3	<0·06	>1·33	Shale, fine sandy
5	70—75	15	15	50	17	3	<0·06	>6·33	Sandstone, medium, argillaceous
6	90—95	78	9	6	6	1	<0·06	1·00	Shale
7	120—125	1	4	50	44	1	0·28	2·32	Sandstone, medium to coarse
8	135—140	8	11	42	34	5	0·09	16·55	do.
9	150—155	4	6	35	52	3	0·20	4·00	Sandstone, coarse to medium
10	155—160	78	8	7	10	2	<0·06	1·00	Shale
11	175—180	21	29	45	4	1	<0·06	>4·83	Sandstone, medium to fine, argillaceous
12	195—200	18	20	52	8	2	<0·06	>4·33	do.
13	200—205	87	6	5	1	1	<0·06	1·00	Shale

See footnotes at end of appendix.

APPENDIX 10—*contd.*

Well B_1, depth 235 feet. Located ¼ mile WSW of Viri. Samples from percussion drill bailer.

Sample No.	Depth of sample below land surface (feet)	Per cent of total by weight					Effective size of grain [1] (millimeters)	Uniformity co-efficient [2]	Field classification of sample
		Silt and clay less than 0·06 mm	Fine sand 0·06 to 0·20 mm	Medium sand 0·20 to 0·60 mm	Coarse sand 0·60 to 2·0 mm	Gravel greater than 2·0 mm			
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
1	15—20	9	14	50	21	6	0·08	4·31	Sandstone, medium to coarse
2	30—33	4	9	25	25	37	0·18	8·72	Sandstone, coarse, conglomeratic
3	41—48	53	24	12	7	4	<0·06	>1·66	Siltstone, fine sandy
4	60—65	2	5	43	49	1	0·25	3·00	Sandstone, coarse to medium
5	80—85	3	6	29	44	18	0·22	5·91	Sandstone, coarse, conglomeratic
6	100—105	3	8	33	47	9	0·18	5·00	Sandstone, coarse to medium
7	125—130	78	2	8	10	2	<0·06	>1·00	Shale
8	140—145	21	25	49	4	1	<0·06	>4·16	Sandstone, medium to fine, argillaceous
9	160—165	5	13	50	29	3	0·14	3·28	Sandstone, medium to coarse
10	170—175	46	33	18	3	0	<0·06	>2·16	Sandstone, fine, silty or siltstone
11	190—195	5	10	52	30	3	0·16	3·12	Sandstone, medium to coarse
12	210—215	5	7	46	34	8	0·17	3·81	do.
13	230—235	39	28	27	5	1	>0·06	>2·83	Shale, fine sandy

See footnotes at end of appendix.

APPENDIX 10—*contd.*

Well B_3, depth 215 feet. Located 3 furlongs W. of Viri. Samples by percussion drill bailer.

Sample No.	Depth of sample below land surface (feet)	Per cent of total by weight					Effective size of grain[1] (milli-meters)	Uniformity co-efficient[2]	Field classification of sample
		Silt and clay less than 0·06 mm	Fine sand 0·06 to 0·20 mm	Medium sand 0·20 to 0·60 mm	Coarse sand 0·60 to 2·0 mm	Gravel greater than 2·0 mm			
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
1	20—25	12	15	59	11	3	<0·06	>5·66	Sandstone, medium to fine
2	35—40	26	31	32	9	2	<0·06	>3·66	Sandstone, medium to fine, argillaceous
3	60—65	3	7	57	31	2	0·20	2·70	Sandstone, medium to coarse
4	70—75	6	12	60	20	2	0·13	3·23	Sandstone, medium to coarse
5	85—90	6	9	37	36	12	0·14	5·71	do.
6	110—115	87	2	4	6	1	<0·06	1·00	Shale
7	130—135	4	11	75	10	0	0·17	2·11	Sandstone, medium
8	155—160	9	15	43	27	6	0·09	5·00	Sandstone, medium to coarse
9	170—175	43	23	19	13	2	<0·06	1·00	Shale, fine sandy
10	185—190	7	8	66	18	1	0·14	2·85	Sandstone, medium to coarse
11	200—205	2	3	43	49	3	0·27	2·78	do.
12	210—215	56	21	11	9	3	<0·06	1·00	Shale, fine sandy

Well BH_1, depth 700 feet. Located 1 5/8 miles SE of Bhadroi. Samples from cores.

Sample No.	Depth of sample below land surface (feet)	Per cent of total by weight					Effective size of grain[1] (milli-meters)	Uniformity co-efficient[2]	Field classification of sample
		Silt and clay less than 0·06 mm	Fine sand 0·06 to 0·20 mm	Medium sand 0·20 to 0·60 mm	Coarse sand 0·60 to 2·0 mm	Gravel greater than 2·0 mm			
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
1	110—115	0	4	35	58	3	0·30	2·90	Sandstone, coarse to medium
2	160—165	0	3	32	59	6	0·33	2·68	do.
3	185—190	1	5	44	46	4	0·25	2·80	do.
4	210—215	1	4	40	49	6	0·26	3·11	do.
5	245—250	0	3	27	60	10	0·34	2·94	do.
6	290—295	1	4	40	52	3	0·30	2·63	do.
7	335—340	1	2	27	63	7	0·35	2·85	do.
8	375—380	1	4	40	52	3	0·27	2·96	do.
									do.

See footnotes at end of appendix.

APPENDIX 10—*contd.*

Well K_2, depth 705 feet. Located one furlong NNW of Khedoi Mota. Samples from cores.

Sample No.	Depth of sample below land surface (feet)	Silt and clay less than 0·06 mm	Per cent of total by weight Fine sand 0·06 to 0·20 mm	Medium sand 0·20 to 0·60 mm	Coarse sand 0·60 to 2·0 mm	Gravel greater than 2·0 mm	Effective size of grain[1] (milli-meters)	Uniformity co-efficient[2]	Field classification of sample
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
1	35—40	7	9	63	19	2	0·17	2·47	Sandstone, medium to coarse
2	60—65	7	20	35	37	2	0·09	6·55	Sandstone, fine to coarse
3	100—105	1	15	58	24	2	0·25	1·80	do.
4	125—130	1	3	50	43	3	0·26	2·54	Sandstone, medium to coarse
5	165—170	15	11	57	16	1	<0·06	>6·66	Sandstone fine to coarse, argillaceous
6	215—220	6	18	68	8	0	0·13	2·46	Sandstone, medium to fine
7	255—260	1	7	64	28	0	0·22	2·27	Sandstone, medium to coarse
8	295—300	0	7	55	38	0	0.25	2·32	do.
9	300—305	2	4	47	45	2	0·26	2·50	do.
10	325—330	5	13	42	39	1	0·14	4·28	do.
11	365—370	2	9	49	39	1	0·18	3·33	do.
12	395—400	6	22	69	3	0	0·12	2·25	Sandstone, medium to fine
13	495—500	3	7	54	35	1	0·20	2·75	Sandstone, medium to coarse
14	540—545	1	3	37	57	2	0·31	2·32	Sandstone, coarse to medium
15	585—590	3	11	51	35	1	0·15	3·73	Sandstone, medium to coarse
16	600—605	1	3	43	46	7	0·31	2·45	Sandstone, coarse to medium
17	695—700	2	11	59	26	2	0·16	3·06	Sandstone, medium to coarse

See footnotes at end of appendix.

APPENDIX 10—*contd.*

Well KH_1, depth 700 feet. Located 5 furlongs east of Khamra. Samples from cores.

Sample No.	Depth of sample below land surface (feet)	Per cent of total by weight: Silt and clay less than 0·06 mm	Per cent of total by weight: Fine sand 0·06 to 0·20 mm	Per cent of total by weight: Medium sand 0·20 to 0·60 mm	Per cent of total by weight: Coarse sand 0·60 to 2·0 mm	Per cent of total by weight: Gravel greater than 2·0 mm	Effective size of grain [1] (milli-meters)	Uniformity co-efficient [2]	Field classification of sample
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
1	35—40	2	13	85	0	0	0·17	2·11	Sandstone, medium to fine
2	80—85	0	0	2	46	52	1·00	2·60	Sandstone, coarse to very coarse, conglomeratic
3	115—120	0	1	21	52	26	0·45	2·77	do.
4	130—135	1	4	30	53	12	0·28	3·50	Sandstone, coarse
5	150—155	0	4	42	46	8	0·32	2·50	do.
6	175—180	2	9	50	34	5	0·19	3·10	Sandstone, medium to coarse
7	190—195	0	3	36	55	6	0·29	3·10	Sandstone, coarse to medium
8	295—300	0	17	55	26	2	0·17	2·64	Sandstone, medium to coarse
9	320—325	2	5	38	53	2	0·24	3·12	do.
10	350—355	6	7	50	35	2	0·14	3·93	do.
11	380—385	3	8	49	38	2	0·19	3·16	do.
12	395—400	0	15	57	26	2	0·17	2·82	do.
13	430—435	2	9	49	39	1	0·19	3·16	do.
14	460—465	5	18	47	29	1	0·13	3·15	Sandstone, medium
15	480—485	3	12	54	30	1	0·17	3·06	do.
16	500—505	1	4	47	43	5	0·25	2·40	Sandstone, medium to coarse
17	525—530	1	9	53	34	3	0·20	2·85	do.
18	550—555	1	16	51	29	3	0·15	3·47	do.
19	570—575	2	18	70	10	0	0·15	2·33	Sandstone, medium
20	595—600	2	16	72	9	1	0·16	2·19	Sandstone, medium to fine
21	620—625	3	10	44	37	6	0·18	3·61	Sandstone, medium to coarse
22	645—650	2	17	63	14	1	0·15	2·33	Sandstone, medium
23	670—675	5	16	59	19	1	0·14	2·86	do.
24	695—700	1	13	63	21	2	0·18	2·44	do.

APPENDIX 10—*concld.*

Well N_1, depth 300 feet. Located 5 furlongs E of Nagalpur. Samples from percussion drill bailer.

Sample No.	Depth of sample below land surface (feet)	Per cent of total by weight					Effective size of grain[1] (millimeters)	Uniformity co-efficient[2]	Field classification of sample
		Silt and clay less than 0·06 mm	Fine sand 0·06 to 0·20 mm	Medium sand 0·20 to 0·60 mm	Coarse sand 0·60 to 2·0 mm	Gravel greater than 2·0 mm			
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
1	53—85	4	21	57	18	0	0·13	3·28	Sandstone, fine to coarse
2	85—114	2	8	43	43	4	0·20	3·50	Sandstone, medium to coarse
3	114—117	14	22	45	17	2	<0·06	<5·83	Sandstone, fine to medium silty
4	117—136	1	4	29	57	9	0·30	3·23	Sandstone, coarse to medium
5	136—157	1	11	59	22	2	0·12	3·91	Sandstone, fine to coarse
6	157—172	3	6	28	49	14	0·22	5·91	Sandstone, coarse to medium; conglomeratic
7	172—261	23	11	33	30	3	<0·06	<8·33	Sandstone, coarse to medium, argillaceous
8	261—263	64	4	16	12	4	<0·06	1·00	Shale, sandy
9	263—268	75	2	9	11	3	<0·06	1·00	Shale
10	268—281	46	11	14	20	9	<0·06	1·00	Siltstone, sandy
11	281—300	10	12	45	29	4	0·06	8·66	Sandstone, medium to coarse

---

[1] Effective size of grain is the diameter of a grain of such size that 10 per cent of the sample (by weight) consists of smaller grains and 90 per cent of larger grains

[2] Uniformity coefficient is the ratio of the diameter of the grain that has 60 per cent of the sample (by weight) finer than itself to the diameter of the grain that has 10 per cent finer than itself

APPENDIX 11

Yield tests of water-bearing zones in exploratory borings in the Anjar-Khedoi region.

(Based on data supplied by John Mowlems Co., Ltd.)

Exploratory borings, A_3, one and a half furlongs south of Viri.

A	Test number	1A	1B
B	Dates of test (1950)	Aug. 30—31	Sept. 1—3
C	Duration of pumping (hours)	24	49
D	Depth of well when tested (feet below land surface)	182	182
E	Position of blank casing (feet below land surface) .	0—60	0—60
F	Diameter of blank casing (inches) . . .	12	12
G	Interval of open hole (feet below land surface) .	60—182	60—182
H	Diameter of open hole (inches)	12	12
I	Footage of water-bearing sandstone tapped by open-hole section.	122	122
J	Static water level (feet below land surface) .	0	0
K	Maximum pumping water level (feet below land surface).	7	26
L	Maximum drawdown (feet)	7	26
M	Average rate of pumping (Imp. gal./min.) . .	161	563
N	Specific capacity of open hole interval (Imp. gal./min./ft. of drawdown).	23·0	21·6
O	Capacity index (1) (specific capacity per foot of open hole).	0·19	0·18
P	Capacity index (2) (spec. cap. per ft. of water-bearing sandstone exposed in open-hole section).	0·19	0·18

APPENDIX 11—*contd.*

Exploratory boring AA_5, one-quarter mile southwest of Viri.

A	Test number . .	1A	1B	2A	2B
B	Dates of test (1950) .	Aug. 16—18	Aug. 18—20	Aug. 26—29	Aug. 30—31
C	Duration of pumping (hours).	53	42	64	35
D	Depth of well when tested (feet below land surface).	95	95	154	154
E	Position of blank casing (feet below land surface).	None	None	0—125	0—125
F	Diameter of blank casing (inches).	Do.	Do.	12	12
G	Interval of open-hole (feet below land surface).	0—95	0—95	125—154	125—154
H	Diameter of open-hole (inches).	12	12	12	12
I	Footage of water-bearing sand stone tapped by open-hole section.	45	45	29	29
J	Static water level (feet below land surface).	3·5	3·5	1·0	1.0
K	Maximum pumping water level (feet below land surface).	13·2	14·2	24·0	42·0
L	Maximum drawdown (feet).	9·7	10·7	23·0	41·0
M	Average rate of pumping (Imp. gal./min.)	291	318	107	167
N	Specific capacity of open-hole interval (Imp. gal./min./ft. of drawdown).	30·0	29·7	4·6	4·1
O	Capacity index (1) (specific capacity per foot of open-hole).	0·33	0·32	0·16	0·14
P	Capacity index (2) (specific capacity per foot of water-bearing sandstone exposed in open-hole section).	0·67	0·66	0·16	0·14

APPENDIX 11—*contd.*

Exploratory boring, BH_1, 1⅝ miles southeast of Bhadrei.

A	Test number . .	1	2	3	4
B	Dates of test (1951) .	Nov. 6—10	Nov. 29—Dec. 26	Dec. 11—15	Dec. 19—23
C	Duration of pumping (hours).	96	84·5	96	96
D	Depth of well when tested (feet below land surface).	255	385	590	700
E	Position of blank casing (feet below land surface).	0—90	0—282	0—282	0—282
F	Diameter of blank casing (inches).	8⅝	8⅝	8⅝	8⅝
G	Interval of open hole (feet below land surface).	90—255	282—385	282—590	282—700
H	Diameter of open hole (inches).	7⅝	7⅝	7⅝	7⅝
I	Footage of water-bearing sandstone tapped by open-hole section.	165	105	140	170
J	Static water level (feet below land surface).	34·9	39·5	39·0	39·0
K	Maximum pumping water level (feet below land surface).	58·5	69·2	66·0	67·0
L	Maximum drawdown (feet).	23·6	29·7	27·0	28·0
M	Average rate of pumping (Imp. gal./min.).	233	121	150	150
N	Specific capacity of open-hole interval (Imp. gal./min./ft. of drawdown).	9·8	4·1	5·5	5·3
O	Capacity index (1) (specific capacity per foot of open-hole).	0·06	0·04	0·02	0·01
P	Capacity index (2) (specific capacity per foot of water-bearing sandstone exposed in open-hole section).	0·06	0·04	0·04	0·03

APPENDIX 11—*contd.*

Exploratory boring, K_2, one furlong NNW of Khedoi Mota.

A	Test number	1A	1B	2	3	4
B	Dates of test (1950)	Aug. 8—12	Aug. 12—15	Aug. 21—24	Sept. 3—5	Sept. 27—30
C	Duration of pumping (hours).	42	72·2	70	48	74·1
D	Depth of well when tested (feet below land surface).	75	75	160	325	705
E	Position of blank casing (feet below land surface).	None	None	0—102	0—190	0—337
F	Diameter of blank casing (inches).	Do.	Do	8	8	8
G	Interval of open-hole (feet below land surface).	0—75	0—75	102—160	190—325	337—705
H	Diameter of open-hole (inches).	9	9	8	8	8
I	Footage of water-bearing sandstone tapped by open-section.	48	48	55	115	322
J	Static water level (feet below land surface).	6·7	6·7	7·1	6·6	6·0
K	Maximum pumping water level (feet below land surface).	13·3	17·0	16·6	24·0	27·0
L	Maximum drawdown (feet).	6·6	10·3	9·5	17·4	21·0
M	Average rate of pumping (Imp. gal./min.)	66	120	280	343	291
N	Specific capacity of open-hole interval (Imp. gal./min./ ft. of drawdown).	10·0	11·6	29·4	19·7	13·8
O	Capacity index (1) (specific capacity per foot of open-hole).	0·15	0·17	0·50	0·15	0·04
P	Capacity index (2) (specific capacity per foot of water-bearing sandstone exposed in open-hole section).	0·21	0·24	0·53	0·17	0·04

APPENDIX 11—*contd.*

Exploratory boring, KH_1, 5 furlongs east of Khamra.

A	Test number	1	2	3	4
B	Dates of test (1951)	July 14—17	July 31—Aug. 2	August 8—10	August 15—18
C	Duration of pumping (hours).	72	45·5	44	72
D	Depth of well when tested (feet below land surface)..	285	420	525	700
E	Position of blank casing (feet below land surface).	0—40	0—315	0—315	0—315
F	Diameter of blank casing (inches).	10	10	10	10
G	Interval of open-hole (feet below land surface).	40—285	315—420	315—525	315—700
H	Diameter of open-hole (inches).	8	8	8	8
I	Footage of water-bearing sandstone tapped by open-hole section.	245	92	156	316
J	Static water level (feet below land surface).	33·0	33·0	33·0	33·0
K	Maximum pumping water level (feet below land surface).	46·0	47·0	51·0	55·0
L	Maximum drawdown (feet).	13·0	14·0	18·0	22·0
M	Average rate of pumping (Imp. gal./min.).	203	106	106	237
N	Specific capacity of open-hole interval (Imp. gal./min./ft. of drawdown).	15·6	7·6	5·9	10·8
O	Capacity index (1) (specific capacity per foot of open-hole).	0·06	0·07	0·03	0·03
P	Capacity index (2) (specific capacity per foot of water-bearing sandstone exposed in open-hole section).	0·06	0·08	0·04	0·03

APPENDIX 11—*contd.*

Exploratory boring, N_1, 5 furlongs east of Nagalpur and 30 feet east of N_2.

A	Test number	1A	1B
B	Dates of test (1950)	August 24—26	August 26—27
C	Duration of pumping (hours)	42	32
D	Depth of well when tested (feet below land surface)	300	300
E	Position of blank casing (feet below land surface)	0—172	0—172
F	Diameter of blank casing (inches) . . .	10	10
G	Interval of open-hole (feet below land surface) .	172—300	172—300
H	Diameter of open-hole (inches)	8	8
I	Footage of water-bearing sandstone tapped by open-hole section.	118	118
J	Static water level (feet below land surface) . .	31·7	31·7
K	Maximum pumping water level (feet below land surface).	54·7	60·1
L	Maximum drawdown (feet)	23·0	28·4
M	Average rate of pumping (Imp. gal./min.) . .	74	93
N	Specific capacity of open-hole interval (Imp. gal./min./ft. of drawdown).	3·2	3·2
O	Capacity index (1) (specific capacity per foot of open-hole).	0·025	0·025
P	Capacity index (2) (specific capacity per foot of water-bearing sandstone exposed in open-hole section).	0·03	0·03

APPENDIX 11—*concld.*

Exploratory boring, N_2, 5 furlongs east of Nagalpur.

A	Test number	1	2	3	4
B	Dates of test (1951)	February 19—20	February 26—March 1	April 10—14	April 21—25
C	Duration of pumping (hours).	24	57·5	96	96
D	Depth of well when tested (feet below land surface).	80	225	520	700
E	Position of blank casing (feet below land surface).	0—30	0—83	0—360	0—360
F	Diameter of blank casing (inches).	8	8	8	8
G	Interval of open-hole (feet below land surface).	30—80	83—225	360—520	360—700
H	Diameter of open-hole (inches).	$7\frac{5}{8}$	$7\frac{5}{8}$	$7\frac{5}{8}$	$7\frac{5}{8}$
I	Footage of water-bearing sandstone tapped by open-hole section.	30	142	160	325
J	Static water level (feet below land surface).	31·0	31·0	33·7	33·7
K	Maximum pumping water level (feet below land surface).	46·0	44·0	44·7	37·7
L	Maximum drawdown (feet).	15·0	13·0	11·0	4·0
M	Average rate of pumping (Imp. gal./min.).	29	268	106	106
N	Specific capacity of open-hole interval (Imp. gal./min./ft. of drawdown).	1·9	20·1	9·6	26·5
O	Capacity index (1) (specific capacity per foot of open-hole).	0·04	0·14	0·06	0·08
P	Capacity index (2) (specific capacity per foot of water-bearing sandstone exposed in open-hole section).	0·06	0·14	0·06	0·08

APPENDIX 12.

Measurements of depth to water in observation wells in the Anjar-Khedoi region, 1951-54.

(Depth to water is in feet below measuring points)

(A) Water levels in production tube wells in the Viri area.

No. A_3. Kandla Port. Supply well, drilled 12 inches in diameter and 220 feet deep. Water from Upper Bhuj sandstones. Measuring point (1) top of 12-inch casing, 1·80 feet above concrete base and land surface, altitude 210·69 feet; (2) top of hole in plate over casing, altitude 210·80 feet. Measurements taken from m.p. (1).

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
1951		1952		1953	
May 31 . .	2·34	May 11 . .	5·02	Jan. 2 . .	3·94
		May 25 . .	5·15	Jan. 9 . .	3·36
June 2 . .	2·27			Jan. 16 . .	3·57
		June 1 . .	5·24	Jan. 23 . .	3·75
Oct. 23 . .	1·60	June 8 . .	5·42	Jan. 30 . .	3·98
Oct. 27 . .	1·70	June 15 . .	5·47		
Oct. 28 . .	1·81	June 22 . .	5·40	Feb. 6 . .	3·92
		June 29 . .	5·25	Feb. 13 . .	3·98
				Feb. 20 . .	4·02
Nov. 15 . .	2·98	July 6 . .	5·40	Feb. 27 . .	4·52
Nov. 22 . .	2·78	July 13 . .	5·07		
Nov. 29 . .	3·19	July 20 . .	3·36	Mar. 6 . .	4·32
		July 27 . .	2·52	Mar. 13 . .	4·67
Dec. 6 . .	2·76			Mar. 20 . .	4·69
Dec. 13 . .	2·92	Aug. 3 . .	2·36	Mar. 27 . .	4·84
Dec. 20 . .	3·00	Aug. 10 . .	1·09		
Dec. 27 . .	2·95	Aug. 17 . .	0·91	Apr. 3 . .	5·07
		Aug. 24 . .	0·95	Apr. 10 . .	5·00
1952		Aug. 31 . .	1·27	Apr. 17 . .	5·23
				Apr. 24 . .	5·43
Jan. 3 . .	3·58	Sept. 7 . .	1·55		
Jan. 9 . .	3·56	Sept. 12 . .	1·65	May 1 . .	5·85
Jan. 16 . .	3·52	Sept. 19 . .	1·72	May 8 . .	5·70
Jan. 23 . .	4·12	Sept. 26 . .	2·22	May 15 . .	6·10
Jan. 30 . .	4·09			May 22 . .	6·00
		Oct. 4 . .	2·49	May 29 .	6·07
Feb. 6 . .	3·32	Oct. 10 . .	2·68		
Feb. 13 . .	3·80	Oct. 17 . .	2·55	June 5 . .	6·07
Feb. 20 . .	3·44	Oct. 24 . .	2·50	June 12 . .	6·27
Feb. 26 . .	3·75	Oct. 31 . .	3·10	June 19 .	6·18
				June 26 . .	6·15
Mar. 4 . .	3·68	Nov. 7 . .	3·34		
Mar. 11 . .	3·84	Nov. 14 . .	3·45	July 1 . .	6·15
Mar. 18 . .	3·92	Nov. 21 . .	3·40	July 2 . .	6·10
Mar. 25 . .	4·16	Nov. 28 . .	3·72	July 3 . .	6·04
Apr. 1 . .	4·24			July 4 . .	6·00
Apr. 8 . .	4·37	Dec. 5 . .	3·74	July 5 . .	5·90
Apr. 15 . .	4·53	Dec. 12 . .	3·80	July 6 . .	6·00
Apr. 22 .	4·61	Dec. 19 . .	3·71	July 7 . .	5·90
Apr. 29 . .	4·71	Dec. 26 . .	3·75	July 8 . .	5·75

APPENDIX 12—*contd.*

No. A_3—*contd.*

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
1953		1953		1953	
July 9	5·85	Aug. 13	3·67	Dec. 4	3·06
July 10	5·80	Aug. 14	3·70	Dec. 11	3·20
July 11	5·80	Aug. 15	3·67	Dec. 18	3·32
July 12	5·78	Aug. 16	3·37	Dec. 25	3·40
July 13	5·48	Aug. 17	3·10		
July 14	5·90	Aug. 18	2·57	1954	
July 16	5·93	Aug. 19	2·50		
July 17	5·88	Aug. 20	1·28	Jan. 1	3·65
July 18	5·90	Aug. 21	1·10	Jan. 8	3·70
July 19	5·85	Aug. 22	0·85	Jan. 15	3·99
July 20	5·40	Aug. 23	0·80	Jan. 22	3·98
July 21	6·00	Aug. 24	0·97	Jan. 29	4·19
July 22	6·05	Aug. 25	0·81		
July 23	6·05	Aug. 26	0·72	Feb. 5	4·39
July 24	6·14	Aug. 27	0·65	Feb. 12	4·60
July 25	6·20	Aug. 28	0·63	Feb. 19	4·62
July 26	6·14	Aug. 29	0·56	Feb. 26	4·58
July 27	6·00	Aug. 30	0·77		
July 28	6·25	Aug. 31	0·80	Mar. 5	4·34
July 29	6·30			Mar. 12	4·62
July 30	6·25	Sept. 4	0·38	Mar. 19	4·80
July 31	6·05	Sept. 11	0·00	Mar. 26	5·05
		Sept. 18	0·54		
Aug. 1	5·40	Sept. 29	0·72	Apr. 2	5·87
Aug. 2	5·35			Apr. 9	5·95
Aug. 3	4·75	Oct. 2	0·94	Apr. 16	6·05
Aug. 4	4·50	Oct. 9	1·28	Apr. 23	6·44
Aug. 5	4·20	Oct. 17	1·74	Apr. 30	6·70
Aug. 6	4·18	Oct. 23	2·20		
Aug. 7	4·09	Oct. 30	2·45	May 7	7·40
Aug. 8	4·15			May 14	7·00
Aug. 9	3·75	Nov. 6	2·45	May 21	7·05
Aug. 10	3·78	Nov. 13	2·66	May 28	6·62
Aug. 11	3·70	Nov. 20	2·82		
Aug. 12	3·60	Nov. 27	3·10	June 4	7·50

APPENDIX 12—*contd.*

No. A_5. Kandla Port. Supply well, drilled 12 inches in diameter and 210 feet deep. Water from Upper Bhuj sandstones. Measuring points (1) top of 12-inch casing, 2·0 feet above land surface, altitude 218·56 feet; (2) top edge of hole for air line in pump base, 1·94 feet above m.p. (1), altitude 220·50 feet. Measurements prior to October 1, 1953 are taken from m.p. (1) and thereafter from m.p. (2).

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
1951		1952		1952	
May 31	7·55	Feb. 6	10·72	Nov. 7	9·96
		Feb. 13	10·58	Nov. 14	10·21
June 2	7·44	Feb. 20	9·43	Nov. 21	10·04
June 12	7·37	Feb. 26	10·32	Nov. 28	10·42
June 19	7·31				
June 26	7·28	Mar. 4	9·86	Dec. 5	10·22
		Mar. 11	9·83	Dec. 12	10·17
July 3	7·44	Mar 18	9·85	Dec. 19	10·02
July 12	7·10	Mar. 25	10·43	Dec. 26	9·94
July 19	7·10				
July 26	7·14	Apr. 1	10·52		
		Apr. 8	10·69		
Aug. 2	6·39	Apr. 15	10·82	1953	
Aug. 9	6·21	Apr. 22	10·84		
Aug. 16	6·00	Apr. 29	11·81	Jan. 2	10·83
Aug. 22	5 86			Jan. 9	9·64
Aug. 30	6·11	May 11	11·36	Jan. 16	10·40
		May 18	11·16	Jan. 23	10·14
Sept. 6	6·37	May 25	11·70	Jan. 30	10·40
Sept. 13	6·49				
Sept. 20	6·64	June 1	11·35	Feb. 6	10·15
Sept. 29	6·85	June 8	11·74	Feb. 13	10·14
		June 15	11·75	Feb. 20	10·26
Oct. 4	7·00	June 22	11·98	Feb. 27	11·08
Oct. 18	7·12	June 29	11·72		
Oct. 23	8·06			Mar. 6	10·90
Oct. 27	7·39	July 6	11·85	Mar. 13	11·21
Oct. 28	9·04	July 13	11·27	Mar. 20	10·90
		July 20	10·83	Mar. 27	11·25
Nov. 12	10·53	July 27	9·26		
Nov. 15	33·25*			Apr. 3	11·95
Nov. 22	34·14*	Aug. 3	8·96		
Nov. 29	35·49*	Aug. 10	7·49	Apr. 10	11·55
		Aug. 17	7·35	Agr. 17	11·66
Dec. 6	11·03	Aug. 24	7·08	Apr. 24	11·90
Dec. 13	33·62*	Aug. 31	7·64		
Dec. 20	9·51			May 1	12·02
Dec. 27	9·09	Sept. 7	8·06	May 8	12·35
		Sept. 12	8·18	May 15	13·05
		Sept. 19	8·08	May 22	12·77
1952		Sept. 26	8·72	May 29	12·79
Jan. 2	36·84*	Oct. 4	9·13		
Jan. 9	36·05*	Oct. 10	9·04	June 5	12.76
Jan. 16	35·20*	Oct. 17	9·30	June 12	13.54
Jan. 23	35·53*	Oct. 24	9·36	June 19	13.02
Jan. 30	13·11	Oct. 31	9·51	June 26	13.54

**Pump operating in well.*

APPENDIX 12—*contd.*

No. ᶠA₅—*contd.*

Date	Depth to water (feet)
1953	
July 1	13·10
July 2	12·97
July 3	12·85
July 4	12·78
July 5	12·65
July 6	12·80
July 7	12·68
July 8	12·60
July 9	12·70
July 10	12·53
July 11	12·45
July 12	12·52
July 13	12·58
July 14	12·60
July 16	12·56
July 17	12·56
July 19	12·75
July 20	12·60
July 23	12·92
July 24	12·83
July 25	13.02
July 26	12·85
July 27	13·10
July 28	13·20
July 29	13·05
July 30	13·10
July 31	13·05
Aug. 1	12·68
Aug. 2	12·50
Aug. 3	11·98
Aug. 4	11·75
Aug. 5	11·45
Aug. 6	11·20
Aug. 7	11·13
1953	
Aug. 8	10·90
Aug. 9	10·78
Aug. 10	10·85
Aug. 11	10·66
Aug. 12	10·58
Aug. 13	10·65
Aug. 14	10·55
Aug. 15	10·58
Aug. 16	10·42
Aug. 17	10·10
Aug. 18	9·87
Aug. 19	9·80
Aug. 20	8·35
Aug. 21	7·86
Aug. 22	7·30
Aug. 23	7·22
Aug. 24	7·12
Aug. 25	7·10
Aug. 26	7·00
Aug. 27	6·62
Aug. 28	6·97
Aug. 29	6·75
Aug. 30	6·75
Aug. 31	7·40
Sept. 4	6·85
Sept. 11	6·47
Sept. 18	6·75
Sept. 29	7·10
Oct. 2	7·25
Oct. 9	7·60
Oct. 16	7·74
Oct. 23	8·15
Oct. 30	9·88
Nov. 6	10·40
Nov. 13	10·56
1953	
Nov. 20	12·15
Nov. 27	12·30
Dec. 4	12·44
Dec. 11	12·58
Dec. 18	12·80
Dec. 25	12·85
1953	
Jan. 1	13·10
Jan. 8	12·87
Jan. 15	13·58
Jan. 22	13·63
Jan. 29	13·90
Feb. 5	14·20
Feb. 12	14·38
Feb. 19	14·42
Feb. 26	14·55
Mar. 5	14·14
Mar. 12	14·05
Mar. 19	14·33
Mar. 26	14·50
Apr. 2	14·87
Apr. 9	14·85
Apr. 16	14·95
Apr. 23	15·55
Apr. 30	15·65
May 7	15·90
May 14	16·05
May 21	16·48
May 28	16·77
June 4	16·88

APPENDIX 12—*contd.*

No. A_6. Kandla Port. Supply well, drilled 12 inches in diameter and 155 feet deep. Water from Upper Bhuj sandstones. Measuring point, top of 12 inch casing, 2·0 feet above land surface; altitude 220·95 feet. Highest daily water level, in feet, below measuring point except as indicated.

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
1951		1951		1952	
June 3	*13·53	Nov. 23	14·10	Jan. 5	14·61
June 26	*13·61	Nov. 24	14·10	Jan. 6	14·61
		Nov. 25	14·16	Jan. 7	14·68
July 3	*13·42	Nov. 26	14·18	Jan. 8	14·67
July 12	*13·50	Nov. 27	14·19	Jan. 9	14·69
July 19	*13·47	Nov. 28	14·23	Jan. 10	14·64
July 26	*13·48	Nov. 29	14·23	Jan. 11	14·65
		Nov. 30	14·21	Jan. 12	14·64
Aug. 3	*12·11			Jan. 13	14·65
Aug. 9	*11·98	Dec. 1	14·23	Jan 14	14·67
Aug. 16	*11·64	Dec. 2	14·18	Jan. 15	14·67
Aug. 22	*11·60	Dec. 3	14·27	Jan. 16	14·70
Aug. 30	*11·89	Dec. 4	14·28	Jan. 17	14·75
		Dec. 5	14·32	Jan. 18	14·75
Sept. 6	*12·09	Dec. 6	14·28	Jan. 19	14·76
Sept. 13	*12·26	Dec. 7	14·24	Jan. 20	14·78
Sept. 20	*12·42	Dec. 8	14·24	Jan. 21	14·79
Sept. 29	*12·72	Dec. 9	14·25	Jan 22	14·81
		Dec. 10	14·27	Jan. 23	14·84
Oct. 4	*12·87	Dec. 11	14·28	Jan. 24	14·89
Oct. 11	*13·05	Dec. 12	14·30	Jan. 25	14·89
Oct. 18	*13·14	Dec. 13	14·32	Jan. 26	14·92
Oct. 23	*13·11	Dec. 14	14·32	Jan. 27	14·92
Oct. 27	*13·22	Dec. 15	14·33	Jan. 28	14·95
Oct. 28	*13·25	Dec. 16	14·32	Jan. 29	14·98
		Dec. 17	14·32	Jan. 30	15·01
Nov. 2	13·40	Dec. 18	14·34	Jan. 31	15·03
Nov. 3	13·44	Dec. 19	14·35		
Nov. 4	13·45	Dec. 20	14·35	Feb. 1	15·04
Nov. 5	13·46	Dec. 21	14·44	Feb. 2	15·10
Nov. 6	13·66	Dec. 22	14·47	Feb. 3	15·10
Nov. 7	13·66	Dec. 23	14·45	Feb. 4	15·12
Nov. 8	13·74	Dec. 24	14·48	Feb. 5	15·05
Nov. 9	13·78	Dec. 25	14·49	Feb. 6	15·07
Nov. 10	13·79	Dec. 26	14·53	Feb. 7	15·00
Nov. 11	13·82	Dec. 27	14·53	Feb. 8	15·01
Nov. 12	13·87	Dec. 28	14·51	Feb. 9	15·00
Nov. 13	13·90	Dec. 29	14·40	Feb. 10	15·01
Nov. 14	14·00	Dec. 30	14·47	Feb. 11	15·02
Nov. 15	14·06	Dec. 31	14·48	Feb. 12	15·03
Nov. 16	14·01			Feb. 13	15·08
Nov. 17	14·00	1952		Feb. 14	15·18
Nov. 18	13·99			Feb. 15	15·13
Nov. 19	13·98	Jan. 1	14·40	Feb. 16	15·18
Nov. 20	13·98	Jan. 2	14·54	Feb. 17	15·18
Nov. 21	14·01	Jan. 3	14·60	Feb. 18	15·17
Nov. 22	14·05	Jan. 4	14·61	Feb. 19	15·25

*Tape measurement.

APPENDIX 12—*contd.*

No. A_6—*contd.*

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
1952		1952		1952	
Feb. 20 . .	15·22	Apr. 12 . .	15·81	June 4 . .	16·99
Feb. 21 . .	15·27	Apr. 13 . .	15·83	June 5 . .	16·96
Feb. 22 . .	15·26	Apr. 14 . .	15·88	June 6 . .	17·01
Feb. 23 . .	15·27	Apr. 15 . .	15·89	June 7 . .	17·04
Feb. 24 . .	15·28	Apr. 16 . .	15·91	June 8 . .	17·00
Feb. 25 . .	15·31	Apr. 17 . .	15·98	June 9 . .	16·97
Feb. 26 . .	15·32	Apr. 18 . .	15·99	June 10 . .	16·98
Feb. 27 . .	15·27	Apr. 19 . .	16·00	June 11 . .	16·98
Feb. 28 . .	15·33	Apr. 20 . .	16·04	June 12 . .	16·98
Feb. 29 . .	15·38	Apr. 21 . .	16·08	June 13 . .	16·96
		Apr. 22 . .	16·10	June 14 . .	16·99
		Apr. 23 . .	16·09	June 15 . .	17·07
Mar. 1 . .	15·39	Apr. 24 . .	16·11	June 16 . .	17·10
Mar. 2 . .	15·39	Apr. 25 . .	16·10	June 17 . .	17·08
Mar. 3 . .	15·30	Apr. 26 . .	16·15	June 18 . .	17·11
Mar. 4 . .	15·42	Apr. 27 . .	16·21	June 19 . .	17·15
Mar. 5 . .	15·42	Apr. 28 . .	16·24	June 20 . .	17·14
Mar. 6 . .	15·41	Apr. 29 . .	16·22	June 21 . .	17·11
Mar. 7 . .	15·38	Apr. 30 . .	16·22	June 22 . .	17·05
Mar 8 . .	15·37			June 23 . .	16·98
Mar. 9 . .	15·39	May 1 . .	16·25	June 24 . .	16·93
Mar. 10 . .	15·37	May 2 . .	16·28	June 25 . .	16·92
Mar 11 . .	15·36	May 3 . .	16·31	June 26 . .	16·90
Mar. 12 . .	15·37	May 4 . .	16·36	June 27 . .	16·90
Mar. 13 . .	15·37	May 5 . .	16·41	June 28 . .	16·85
Mar. 14 . .	15·38	May 6 . .	16·41	June 29 . .	16·84
Mar. 15 . .	15·38	May 7 . .	16·46	June 30 . .	16·84
Mar. 16 . .	15·39	May 8 . .	16·48		
Mar. 17 . .	15·42	May 9 . .	16·45	July 1 . .	16·86
Mar. 18 . .	15·41	May 10 . .	16·49	July 2 . .	16·85
Mar. 19 . .	15·46	May 11 . .	16·46	July 3 . .	16·85
Mar. 20 . .	15·48	May 12 . .	16·52	July 4 . .	16·85
Mar. 21 . .	15·48	May 13 . .	16·52	July 5 . .	16·83
Mar. 22 . .	15·48	May 14 . .	16·57	July 6 . .	16·85
Mar. 23 . .	15·48	May 15 . .	16·60		
Mar. 24 . .	15·50	May 16 . .	16·65		
Mar. 25 . .	15·52	May 17 . .	16·69	July 7 . .	16·88
Mar. 26 . .	15·50	May 18 . .	16·71	July 8 . .	16·91
Mar. 27 . .	15·56	May 19 . .	16·73	July 9 . .	16·93
Mar. 28 . .	15·54	May 20 . .	16·75	July 10 . .	16·84
Mar. 29 . .	15·56	May 21 . .	16·72	July 11 . .	16·83
Mar. 30 . .	15·58	May 22 . .	16·70	July 12 . .	16·86
Mar. 31 . .	15·63	May 23 . .	16·67	July 13 . .	16·85
		May 24 . .	16·69	July 14 . .	16·81
		May 25 . .	16·72	July 15 . .	16·79
Apr. 1 . .	15·62	May 26 . .	16·73	July 16 . .	16·71
Apr. 2 . .	15·66	May 27 . .	16·78	July 17 . .	16·40
Apr. 3 . .	15·66	May 28 . .	16·79	July 18 . .	16·10
Apr. 4 . .	15·70	May 29 . .	16·84	July 19 . .	15·90
Apr. 5 . .	15·70	May 30 . .	16·87	July 20 . .	15·10
Apr. 6 . .	15·72	May 31 . .	16·93	July 21 . .	14·37
Apr. 7 . .	15·75			July 22 . .	13·95
Apr. 8 . .	15·73	June 1 . .	16·91	July 23 . .	13·75
Apr. 9 . .	15·73	June 2 . .	16·94	July 24 . .	13·64
Apr. 10 . .	15·76	June 3 . .	16·97	July 25 . .	13·50

APPENDIX 12—*contd.*

No. A_6—*contd.*

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
1952		1952		1952	
July 26	13·40	Oct. 11	12·91	Dec. 4	14·57
July 27	*13·30	Oct. 12	12·93	Dec. 5	14·60
		Oct. 13	12·93	Dec. 6	14·63
Aug. 3	*12·70	Oct. 14	12·95	Dec. 7	14·64
Aug. 4	12·62	Oct. 15	12·98	Dec. 11	*14·73
Aug. 10	*10·88	Oct. 16	12.98	Dec. 12	14·72
Aug. 11	10·80	Oct. 17	13·02	Dec. 17	14·84
Aug. 12	10·78	Oct. 18	13·06	Dec. 18	14·87
Aug. 17	*10·84	Oct. 19	13·08	Dec. 19	14·88
Aug. 18	10·76	Oct. 20	13·10	Dec. 20	14·91
Aug. 19	10·78	Oct. 21	13·14	Dec. 21	14·91
Aug. 22	10·85	Oct. 22	13·15	Dec. 22	14·91
Aug. 23	10·86	Oct. 23	13·19	Dec. 23	14·92
Aug. 24	10·88	Oct. 24	13·21	Dec. 24	14·94
Aug. 25	10·88	Oct. 25	13·25	Dec. 25	14·95
Aug. 26	10·91	Oct. 26	13·28	Dec. 26	14·93
Aug. 27	10·96	Oct. 27	13·30	Dec. 27	14·94
Aug. 28	11·01	Oct. 28	13·33	Dec. 28	14·96
Aug. 29	12·28	Oct. 20	13·36	Dec. 29	15·00
Aug. 30	11·12	Oct. 30	13·43	Dec. 30	15·03
Aug. 31	11·17	Oct. 31	13·47	Dec. 31	15·06
Sept. 8	11·52	Nov. 1	13·47	1953	
Sept. 9	11·50	Nov. 2	13·50		
Sept. 10	11·52	Nov. 3	13·54	Jan. 1	15·10
Sept. 11	11·56	Nov. 4	13·60	Jan. 2	15·12
Sept. 12	11·63	Nov. 5	13·63	Jan. 3	15·14
Sept. 13	11·66	Nov. 6	13·70	Jan. 4	15·13
Sept. 14	11·72	Nov. 7	13·74	Jan. 5	15·12
Sept. 15	11·75	Nov. 8	13·83	Jan. 6	14·63
Sept. 16	11·77	Nov. 9	13·89	Jan. 7	14·58
Sept. 20	11·91	Nov. 10	13·95	Jan. 8	14·53
Sept. 21	11·94	Nov. 11	13·99	Jan. 9	14·47
Sept. 22	11·99	Nov. 12	14·01	Jan. 10	14·42
Sept. 23	12·04	Nov. 13	14·04	Jan. 11	14·40
Sept. 24	12·08	Nov. 14	14·06	Jan. 12	14·43
Sept. 26	12·18	Nov. 15	14·09	Jan. 13	14·48
Sept. 27	12·21	Nov. 16	14·12	Jan. 14	14·54
Sept. 28	12·26	Nov. 17	14·17	Jan. 15	14·57
Sept. 29	12·28	Nov. 18	14·21	Jan. 16	14·62
Sept. 30	12·33	Nov. 19	14·23	Jan. 17	14·70
		Nov. 20	14·24	Jan. 18	14·73
Oct. 1	12·35	Nov. 21	14·26	Jan. 19	14·74
Oct. 2	12·39	Nov. 25	14·35	Jan. 20	14·75
Oct. 3	12·47	Nov. 26	14·35	Jan. 21	14·75
Oct. 4	12·52	Nov. 27	14·40	Jan. 22	14·73
Oct. 5	12·60	Nov. 28	14·45	Jan. 23	14·74
Oct. 6	12·67	Nov. 29	14·49	Jan. 24	14·77
Oct. 7	12·71	Nov. 30	14·52	Jan. 25	14·78
Oct. 8	12·74	Dec. 1	14·56	Jan. 26	14·83
Oct. 9	12·79	Dec. 2	14·54	Jan. 27	14·85
Oct. 10	12·86	Dec. 3	14·56	Jan. 28	14·87

*Tape measurement.

APPENDIX 12—*contd.*

No. A_6—*contd.*

Date	Depth to water (feet)
1953	
Jan. 29	14·88
Jan. 30	14·92
Jan. 31	14·95
Feb. 1	14·98
Feb. 2	15·00
Feb. 3	15·01
Feb. 4	15·00
Feb. 5	15·00
Feb. 6	15·02
Feb. 7	15·04
Feb. 8	15·09
Feb. 9	15·13
Feb. 10	15·18
Feb. 11	15·21
Feb. 12	15·23
Feb. 13	15·23
Feb. 14	15·29
Feb. 15	15·29
Feb. 16	15·30
Feb. 17	15·31
Feb. 18	15·32
Feb. 19	15·34
Feb. 20	15·36
Feb. 21	15·43
Feb. 22	15·45
Feb. 23	15·49
Feb. 24	15·50
Feb. 25	15·54
Feb. 26	15·57
Feb. 27	15·59
Feb. 28	15·59
Mar. 1	15·62
Mar. 2	15·56
Mar. 3	15·61
Mar. 4	15·59
Mar. 5	15·59
Mar. 6	15·59
Mar. 7	15·65
Mar. 8	15·70
Mar. 9	15·74
Mar. 10	15·78
Mar. 11	15·78
Mar. 12	15·84
Mar. 13	15·87
Mar. 14	15·84
Mar. 15	15·83
Mar. 16	15·82
Mar. 17	15·82
Mar. 18	15·84
Mar. 19	15·86
1953	
Mar. 20	15·87
Mar. 21	15·94
Mar. 22	15·99
Mar. 23	16·05
Mar. 24	16·06
Mar. 25	16·10
Mar. 26	16·12
Mar. 27	16·17
Mar. 28	16·16
Mar. 29	16·16
Mar. 30	16·18
Mar. 31	16·20
Apr. 1	16·20
Apr. 2	16·20
Apr. 3	16·23
Apr. 4	16·32
Apr. 5	16·36
Apr. 6	16·37
Apr. 7	16·42
Apr. 8	16·45
Apr. 9	16·50
Apr. 10	16·57
Apr. 11	16·55
Apr. 12	16·56
Apr. 13	16·55
Apr. 14	16·51
Apr. 15	16·54
Apr. 16	16·56
Apr. 17	16·57
Apr. 24	*16·92
Apr. 25	16·88
Apr. 26	16·90
Apr. 27	16·90
Apr. 28	16·92
Apr. 29	16·93
Apr. 30	16·92
May 1	16·94
May 2	17·00
May 3	17·06
May 4	17·11
May 5	17·12
May 6	17·17
May 7	17·20
May 8	17·24
May 9	17·24
May 10	17·24
May 11	17·23
May 12	17·23
May 13	17·22
May 14	17·19
1953	
May 15	17·25
May 16	17·22
May 17	17·24
May 18	17·33
May 19	17·34
May 20	17·36
May 21	17·39
May 22	17·42
May 23	17·39
May 24	17·39
May 25	17·39
May 26	17·38
May 27	17·38
May 28	17·39
May 29	17·39
May 30	17·48
May 31	17·53
June 1	17·54
June 2	17·56
June 3	17·61
June 4	17·66
June 5	17·56
June 6	17·67
June 7	17·64
June 8	17·60
June 9	17·59
June 10	17·62
June 11	17·59
June 12	17·60
June 13	17·67
June 14	17·69
June 15	17·72
June 16	17·76
June 17	17·76
June 18	17·75
June 19	17·77
June 20	17·74
June 21	17·71
June 22	17·65
June 23	17·67
June 24	17·68
June 25	17·71
June 26	17·69
June 27	17·74
June 28	17·76
June 29	17·72
June 30	17·71
July 1	17·74
July 2	17·70
July 3	17·66

---

* *Tape measurement.*

APPENDIX 12—*contd.*

No. A_6—*contd.*

Date	Depth to Water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
1953		1953		1953	
July 4	17·64	Sept. 1	10·21	Oct. 24	11·89
July 5	17·59	Sept. 2	10·21	Oct. 25	11·95
July 6	17·58	Sept. 3	10·21	Oct. 26	12·00
July 7	17·53	Sept. 4	10·24	Oct. 27	12·06
July 8	17·47	Sept. 5	9·94	Oct. 28	12·07
July 9	17·42	Sept. 6	9·87	Oct. 29	12·12
July 10	17·40	Sept. 7	9·86	Oct. 30	12·16
July 11	17·42	Sept. 8	9·87	Oct. 31	12·20
July 12	17·43	Sept. 9	9·88		
July 13	17·44	Sept. 10	9·94	Nov. 1	12·24
July 14	17·46	Sept. 11	10·00	Nov. 2	12·25
July 15	17·52	Sept. 12	10·01	Nov. 3	12·27
July 16	17·54	Sept. 13	10·04	Nov. 4	12·32
July 17	17·56	Sept. 14	10·07	Nov. 5	12·35
July 18	17·51	Sept. 15	10·08	Nov. 6	12·41
July 19	17·48	Sept. 16	10·19	Nov. 7	12·43
July 20	17·46	Sept. 17	10·28	Nov. 10	*12·66
July 21	17·53	Sept. 18	10·33	Nov. 11	12·57
July 22	17·55	Sept. 19	10·40	Nov. 12	12·59
July 23	17·58	Sept. 20	10·44	Nov. 13	12·64
July 24	*17·85	Sept. 21	10·50	Nov. 14	12·68
July 25	17·65	Sept. 22	10·51	Nov. 15	12·72
July 26	17·69	Sept. 23	10·58	Nov. 16	12·77
July 27	17·72	Sept. 24	10·63	Nov. 17	12·80
July 28	17·77	Sept. 25	10·70	Nov. 18	12·80
July 29	17·81	Sept. 26	10·74	Nov. 19	12·82
July 30	17·84	Sept. 27	10·79	Nov. 20	12·89
July 31	*17·78	Sept. 28	10·83		
		Sept. 29	10·88	Dec. 5	13·33
Aug. 3	*15·72	Sept. 30	10·92	Dec. 6	13·36
Aug. 4	*15·40			Dec. 7	13·38
Aug. 5	14·87	Oct. 1	10·95	Dec. 8	13·43
Aug. 6	14·75	Oct. 2	10·95	Dec. 9	13·49
Aug. 7	14·77	Oct. 3	11·00	Dec. 10	13·60
Aug. 12	14·20	Oct. 4	11·07	Dec. 11	13·63
Aug. 13	14·18	Oct. 5	11·12	Dec. 12	13·69
Aug. 14	14·18	Oct. 6	11·04	Dec. 13	13·69
Aug. 15	14·13	Oct. 7	11·20	Dec. 14	13·75
Aug. 16	13·50	Oct. 8	11·21	Dec. 15	13·78
Aug. 17	13·00	Oct. 9	11·29	Dec. 16	13·80
Aug. 18	12·70	Oct. 10	11·33	Dec. 17	13·84
Aug. 19	11·10	Oct. 11	11·38	Dec. 18	13·88
Aug. 20	10·70	Oct. 12	11·42	Dec. 19	13·85
Aug. 21	10·50	Oct. 13	11·47	Dec. 20	13·88
Aug. 22	10·39	Oct. 14	11·53	Dec. 21	13·93
Aug. 23	10·31	Oct. 15	11·55	Dec. 22	13·96
Aug. 24	10·27	Oct. 16	11·56	Dec. 23	13·95
Aug. 25	10·25	Oct. 17	11·60	Dec. 24	14·01
Aug. 26	10·24	Oct. 18	11·64	Dec. 25	14·00
Aug. 27	10·24	Oct. 19	11·68	Dec. 26	14·00
Aug. 28	10·24	Oct. 20	11·69	Dec. 27	14·03
Aug. 29	10·22	Oct. 21	11·75	Dec. 28	14·07
Aug. 30	10·21	Oct. 22	11·84	Dec. 29	14·07
Aug. 31	10·21	Oct. 23	11·85	Dec. 30	14·07

---

* *Tape measurement.*

APPENDIX 12—*contd.*

No. A_6—*contd.*

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
1954		1954		1954	
Jan. 2	14·17	Feb. 23	15·51	Apr. 15	16·75
Jan. 3	14·18	Feb. 24	15·55	Apr. 16	16·81
Jan. 4	14·18	Feb. 25	15·59	Apr. 17	16·87
Jan. 5	14·20	Feb. 26	15·63	Apr. 18	16·92
Jan. 6	14·21	Feb. 27	15·62	Apr. 19	16·97
Jan. 7	14·23	Feb. 28	15·67	Apr. 20	17·01
Jan. 8	14·24			Apr. 21	17·05
Jan. 9	14·28	Mar. 1	15·71	Apr. 22	17·09
Jan. 10	14·29	Mar. 2	15·75	Apr. 23	17·14
Jan. 11	14·31	Mar. 3	15·77	Apr. 24	17·11
Jan. 12	14·33	Mar. 4	15·79	Apr. 25	17·13
Jan. 13	14·34	Mar. 5	15·83	Apr. 26	17·18
Jan. 14	14·37	Mar. 6	15·98	Apr. 27	17·23
Jan. 15	14·42	Mar. 7	16·02	Apr. 28	17·24
Jan. 16	14·43	Mar. 8	16·07	Apr. 29	17·31
Jan. 17	14·43	Mar. 9	16·03	Apr. 30	17·32
Jan. 18	14·44	Mar. 10	16·00		
Jan. 19	14·45	Mar. 11	16·00	May 1	17·31
Jan. 20	14·50	Mar. 12	16·00	May 2	17·30
Jan. 21	14·55	Mar. 13	15·93	May 3	17·31
Jan. 22	14·56	Mar. 14	15·91	May 4	17·37
Jan. 23	14·58	Mar. 15	15·93	May 5	17·46
Jan. 24	14·65	Mar. 16	15·95	May 6	17·46
Jan. 25	14·65	Mar. 17	15·99	May 7	17·47
Jan. 26	14·70	Mar. 18	16·02	May 8	17·53
Jan. 27	14·72	Mar. 19	16·10	May 9	17·57
Jan. 28	14·77	Mar. 20	16·07	May 10	17·60
Jan. 29	14·80	Mar. 21	16·04	May 11	17·62
Jan. 30	14·80	Mar. 22	16·09	May 12	17·65
Jan. 31	14·83	Mar. 23	16·11	May 13	17·69
		Mar. 24	16·10	May 14	17·65
Feb. 1	14·81	Mar. 25	16·13	May 15	17·77
Feb. 2	14·80	Mar. 26	16·13	May 16	17·79
Feb. 3	14·82	Mar. 27	16·22	May 17	17·84
Feb. 4	14·85	Mar. 28	16·21	May 18	17·85
Feb. 5	14·90	Mar. 29	16·22	May 19	17·89
Feb. 6	14·91	Mar. 30	16·28	May 20	17·92
Feb. 7	14·95	Mar. 31	16·44	May 21	18·03
Feb. 8	14·01			May 22	18·11
Feb. 9	15·02	Apr. 1	16·34	May 23	18·13
Feb. 10	15·06	Apr. 2	16·32	May 24	18·15
Feb. 11	15·12	Apr. 3	16·38	May 25	18·23
Feb. 12	15·15	Apr. 4	16·41	May 26	18·23
Feb. 13	15·30	Apr. 5	16·44	May 27	18·26
Feb. 14	15·33	Apr. 6	16·47	May 28	18·29
Feb. 15	15·37	Apr. 7	16·50	May 29	18·37
Feb. 16	15·37	Apr. 8	16·55	May 30	18·35
Feb. 17	15·40	Apr. 9	16·59	May 31	18·37
Feb. 18	15·41	Apr. 10	16·67		
Feb. 19	15·40	Apr. 11	16·67	June 1	18·37
Feb. 20	15·55	Apr. 12	16·69	June 2	18·38
Feb. 21	15·49	Apr. 13	16·66	June 3	18·43
Feb. 22	15·49	Apr. 14	16·72	June 4	18·44

APPENDIX 12—*contd.*

No. B_1. Kandla Port. Supply well, drilled 12 inches in diameter and 220 feet deep. Water from Upper Bhuj sandstones. Measuring points (1) top of 12 inch casing coupling, 3·08 feet above concrete base and land surface, altitude 224·74 feet; (2) top of concrete pump support, 1·00 feet above m.p. (1), altitude 225·74; (3) top of plug in pump-base, 1·24 feet above m.p. (1), altitude 225·98 feet. Measurements prior to May 18, 1952 are taken from m.p. (1) and thereafter from m.p. (3).

Date	Depth to water (feet)
1951	
May 31	14·55
June 1	14·49
Oct. 27	14·68
Oct. 28	14·76
Nov. 15	16·40
Nov. 22	16·20
Nov. 29	16·40
Dec. 6	15·97
Dec. 13	16·32
Dec. 20	20·00
Dec. 27	16·25
1952	
Jan. 3	16·85
Jan. 9	16·79
Jan. 23	16·74
Jan. 30	17·07
Feb. 6	16·51
Feb. 13	17·86
Feb. 20	17·57
Feb. 26	38·84*
Mar. 4	18·11
Mar. 11	17·33
Mar. 18	17·34
Mar. 25	18·34
Apr. 1	18·67
Apr. 8	18·65
Apr. 15	18·96
Apr. 22	18·36
Apr. 29	19·15
May 11	19·83
May 18	19·54
May 25	21·03
1952	
June 1	20·91
June 8	20·70
June 15	20·98
June 22	20·82
June 29	20·33
July 6	20·50
July 13	20·20
July 20	19·33
July 27	17·96
Aug. 3	17·05
Aug. 10	15·60
Aug. 17	14·91
Aug. 24	14·83
Aug. 31	15·82
Sept. 7	16·48
Sept. 12	16·63
Sept. 19	16·07
Sept. 26	17·12
Oct. 4	17·83
Oct. 10	17·98
Oct. 17	17·91
Oct. 24	17·90
Oct. 31	18·28
Nov. 7	18·56
Nov. 14	18·85
Nov. 21	19·10
Nov. 28	19·50
Dec. 5	18·90
Dec. 12	18·53
Dec. 19	19·05
Dec. 26	18·59
1953	
Jan. 2	19·02
Jan. 9	18·26
1953	
Jan. 16	18·48
Jan. 23	18·74
Jan. 30	18·90
Feb. 6	18·80
Feb. 13	19·14
Feb. 20	19·00
Feb. 27	19·87
Mar. 6	19·26
Mar. 13	20·28
Mar. 20	19·65
Mar. 27	20·10
Apr. 3	20·10
Apr. 10	20·55
Apr. 17	20·65
Apr. 24	21·00
May 1	20·85
May 8	21·48
May 15	22·49
May 22	21·68
May 29	21·69
June 5	21·72
June 12	21·57
June 19	21·75
June 26	21·55
July 1	21·72
July 2	21·52
July 3	21·40
July 4	21·30
July 5	21·14
July 6	21·16
July 7	21·02
July 8	20·95
July 9	21·00
July 10	21·00
July 11	21·10
July 12	21·12
July 13	21·12

*Pump operating in well.

APPENDIX 12—*contd.*

No. B_1—*contd.*

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
1953		1953		1953	
July 14	21·20	Aug. 16	18·85	Dec. 4	18·18
July 16	21·54	Aug. 17	18·40	Dec. 11	18·20
July 17	21·35	Aug. 18	18·47	Dec. 17	18·18
July 18	21·20	Aug. 19	18·40	Dec. 25	18·20
July 19	21·25	Aug. 20	15·38	1954	
July 20	21·24	Aug. 21	15·65	Jan. 1	18·46
July 21	21·30	Aug. 22	14·85	Jan. 8	18·62
July 22	21·30	Aug. 23	14·70	Jan. 15	18·64
July 23	21·25	Aug. 24	14·62	Jan. 22	19·02
July 24	21·40	Aug. 25	14·66	Jan. 29	19·18
July 25	21·50	Aug. 26	14·50		
July 26	21·60	Aug. 27	14·40	Feb. 5	19·30
July 27	21·75	Aug. 28	14·50	Feb. 12	19·56
July 28	21·75	Aug. 29	14·20	Feb. 19	19·58
July 29	21·90	Aug. 30	14·40	Feb. 26	19·78
July 30	21·82	Aug. 31	14·62		
July 31	21·65			Mar. 5	20·28
		Sept. 4	14·32	Mar. 12	19·63
Aug. 1	21·25	Sept. 11	14·05	Mar. 19	19·90
Aug. 2	21·15	Sept. 18	14·65	Mar. 26	19·90
Aug. 3	20·65	Sept. 29	15·30		
Aug. 4	20·35			Apr. 2	19·88
Aug. 5	20·10	Oct. 2	15·37	Apr. 9	21·02
Aug. 6	19·75	Oct. 9	15·77	Apr. 16	21·65
Aug. 7	19·66	Oct. 16	16·17	Apr. 23	22·27
Aug. 8	19·46	Oct. 23	16·62	Apr. 30	22·30
Aug. 9	19·40	Oct. 30	17·08		
Aug. 10	19·40			May 7	22·20
Aug. 11	19·25			May 14	22·50
Aug. 12	19·05	Nov. 6	17·10	May 21	22·28
Aug. 13	19·15	Nov. 13	17·32	May 28	22·07
Aug. 14	19·06	Nov. 20	17·50		
Aug. 15	18·97	Nov. 28	17·90	June 4	22·71

APPENDIX 12—*contd.*

No. B$_3$ Kandla Port Supply well, drilled 12 inches in diameter and 215 feet deep. Water from Upper Bhuj sandstones. Measuring points (1) top of 12-inch casing, 2·0 feet above land surface, altitude 232·87 feet; (2) top of concrete platform, 1·00 foot above m.p. (1) altitude 237·87 feet; (3) top of plug in pump base, 1·24 feet above m.p. (1), altitude 234·11 feet. Depth to water measurements referred to m.p. (3).

Date	Depth to water (feet)
1951	
June 2	21·90
Oct. 23	21·68
Oct. 27	21·87
Oct. 28	21·99
Nov. 15	22·96
Nov. 22	22·84
Nov. 29	23·49
Dec. 6	46·90*
Dec. 13	23·53
Dec. 20	24·47
Dec. 27	46·02*
1952	
Jan. 3	24·16
Jan. 9	24·01
Jan. 16	24·05
Jan. 23	24·54
Jan. 30	24·46
Feb. 6	49·30*
Feb. 13	25·97
Feb. 20	53·86*
Mar. 4	59·36*
Mar. 11	59·99*
Mar. 25	25·94
Apr. 1	30·41
Apr. 8	27·74
Apr. 15	56·73*
Apr. 22	57·11*
Apr. 29	43·18*
May 11	60·84*
May 18	26·60
May 25	62·05*
June 1	26·72
June 8	27·16
June 15	26·93
June 22	27·54
June 29	27·40
1952	
July 6	26·95
July 13	26·66
July 20	26·40
July 27	24·67
Aug. 3	24·70
Aug. 10	24·66
Aug. 17	24·65
Aug. 24	22·84
Aug. 31	21·68
Sept. 7	26·07
Sept. 12	25·62
Sept. 19	24·30
Sept. 26	25·04
Oct. 4	23·68
Oct. 10	25·93
Oct. 17	52·50*
Oct. 24	52·85*
Oct. 31	28·54
Nov. 7	26·91
Nov. 14	26·92
Nov. 21	25·38
Nov. 28	25·73
Dec. 5	25·90
Dec. 12	25·83
Dec. 19	25·40
Dec. 26	25·35
1953	
Jan. 2	25·43
Jan. 9	25·14
Jan. 16	24·95
Jan. 25	25·50
Jan. 30	25·86
Feb. 6	25·60
Feb. 13	25·44
Feb. 20	25·52
Feb. 27	26·53
Mar. 6	25·78
Mar. 13	26·65
1953	
Mar. 20	26·32
Mar. 27	26·87
Apr. 3	26·70
Apr. 10	26·98
Apr. 17	27·15
Apr. 24	27·53
May 1	28·00
May 8	27·70
May 15	28·44
May 22	28·10
May 29	28·06
June 5	28·00
June 12	28·18
June 19	27·90
June 26	22·65
July 1	28·18
July 2	28·00
July 3	28·07
July 4	27·98
July 5	27·85
July 6	28·05
July 7	27·90
July 8	27·85
July 9	28·10
July 10	27·60
July 11	27·56
July 12	27·48
July 13	27·55
July 14	27·45
July 16	27·63
July 17	27·75
July 18	27·84
July 19	28·07
July 20	28·20
July 21	28·00
July 22	28·25
July 23	28·20
July 24	28·10
July 25	28·05
July 26	27·90
July 27	27·95

* *Pump operating in well.*

APPENDIX 12—*contd.*

No. B_3—*contd.*

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
1953		1953		1953	
July 28 .	. 28·10	Aug. 23 .	. 22·70	Dec. 18 .	. 24·50
July 29 .	. 28·08	Aug. 24 .	. 22·55	Dec. 25 .	. 24·43
July 30 .	. 27·98	Aug. 25 .	. 22·45	1954	
July 31 .	. 28·10	Aug. 26 .	. 22·30	Jan. 1 .	. 24·68
		Aug. 27 .	. 22·10	Jan. 8 .	. 24·75
		Aug. 28 .	. 22·45	Jan. 15 .	. 24·88
		Aug. 20 .	. 21·97	Jan. 22 .	. 25·10
Aug. 1 .	. 27·90	Aug. 30 .	. 22·10	Jan. 29 .	. 25·20
Aug. 2 .	. 27·90	Aug. 31 .	. 22·20	Feb. 5 .	. 25·37
Aug. 3 .	. 27·35			Feb. 12 .	. 25·38
Aug. 4 .	. 27·15			Feb. 19 .	. 25·68
Aug. 5 .	. 27·15	Sept. 4 .	. 21·73	Feb. 26 .	. 25·85
Aug. 6 .	. 26·72	Sept. 11 .	. 21·45		
Aug. 7 .	. 26·48	Sept. 18 .	. 21·40	Mar. 5 .	. 25·72
Aug. 8 .	. 26·23	Sept. 29 .	. 21·82	Mar. 12 .	. 25·85
Aug. 9 .	. 26·15			Mar. 19 .	. 26·10
Aug. 10 .	. 26·14	Oct. 2 .	. 22·07	Mar. 26 .	. 26·35
Aug. 11 .	. 26·00	Oct. 9 .	. 22·30		
Aug. 12 .	. 25·82	Oct. 16 .	. 23·36	Apr. 2 .	. 26·67
Aug. 13 .	. 25·80	Oct. 23 .	. 23·19	Apr. 9 .	. 27·70
Aug. 14 .	. 26·02	Oct. 30 .	. 23·40	Apr. 16 .	. 27·10
Aug. 15 .	. 26·15			Apr. 23 .	. 27·20
Aug. 16 .	. 25·85	Nov. 6 .	. 23·48	Apr. 30 .	. 27·40
Aug. 17 .	. 25·57	Nov. 13 .	. 23·66	May 7 .	. 28·05
Aug. 18 .	. 25·50	Nov. 20 .	. 23·88	May 14 .	. 27·90
Aug. 19 .	. 24·80	Nov. 27 .	. 24·28	May 21 .	. 28·00
Aug. 20 .	. 24·00			May 28 .	. 28·13
Aug. 21 .	. 23·68	Dec. 4 .	. 24·33		
Aug. 22 .	. 22·95	Dec. 11 .	. 24·42	June 4	28·75

(Depth to water is in feet below measuring point.)

(B) Water levels in observation wells of the Anjar-Khedoi region.

No. 1P. Juma Ladda. Irrigation well, dug 8 by 9 feet across and 23 feet deep. Water from Upper Bhuj sandstone. Measuring point, above land surface ; altitude 212·38 feet.

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
Mar. 30, 1951 .	11·81				
June 4, 1951 .	12·20	Oct. 24, 1951 .	11·93	May 15, 1952 .	13·01

APPENDIX 12—*contd.*

No. 2P. Juma Ladda. Irrigation well, dug 7 by 9 feet across and 21 feet deep. Water from Upper Bhuj sandstone. Measuring point arrow on sandstone slab centre of West side, 2·0 feet above land surface ; altitude 212·12 feet.

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
Mar. 30, 1951 .	11·23				
June 4, 1951 .	11·78	Oct. 24, 1951 .	11.88	May 15, 1952 .	12·65

No. 3P. Juma Ladda. Irrigation well, dug 7 by 8 feet across and 25 feet deep. Water from Deccan traps. Measuring point arrow on sandstone slab centre, North side, 1·0 foot above land surface ; altitude 210·90 feet.

Mar. 30, 1951 .	11·13	June 4, 1951 .	11·07	Oct. 24, 1951 .	10·16

No. 7P. Khanji Bhimji. Irrigation well, dug 12 feet square and 31 feet deep. Water from Upper Bhuj sandstone. Measuring point arrow on sandstone slab centre of North side, 2·0 feet above land surface altitude 220·86 feet.

Mar. 30, 1951 .	21·15				
June 4, 1951 .	20·55	Oct. 24, 1951 .	20·17	May 15, 1952 .	28·22*

No. 9P. Owner unknown. Irrigation well, dug 7 by 8 feet across and 30 feet deep then one boring 48 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on sandstone slab Southeast corner 2·0 feet above land surface ; altitude 225·88 feet.

Mar. 30, 1951 .	25·41				
June 4, 1951 .	26·12	Oct. 24, 1951 .	26·66	May 15, 1952 .	27·16

No. 13P. Walji Sutar. Irrigation well, dug 45 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on projecting sandstone slab, East side, 2·0 feet above land surface ; altitude 219·70 feet.

Mar. 31, 1951 .	26·85				
June 6, 1951 .	31·12*	Nov. 11, 1951 .	36·63*	May 12, 1952 .	40·68*

* *Pumping water level.*

APPENDIX 12—*contd.*

No. 21P. Owner unknown. Unused well, dug 30 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on sandstone slab centre of Northwest side, 3·0 feet above land surface; altitude 224·88 feet.

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
Apr 6, 1951	15·88				
June 2, 1951	16·61	Oct. 24, 1951	16·34	May 15, 1952	21·68

No. 22P. Kasu Karu. Irrigation well, dug 7 feet square and 17 feet deep. Water from Deccan traps. Measuring point, arrow on lip of sandstone slab centre of East side, 1·0 foot above land surface; altitude 219·02 feet.

Apr. 8, 1951	11·87				
June 3, 1951	12·05	Oct. 24, 1951	12·09	May 15, 1952	15·57

No. 24P. Ablu Dinmohmud. Irrigation well dug 7 feet square and 26 feet deep. Water from Deccan traps. Measuring points, (1) on April 8, 1951, top of curb South side 6·0 feet above land surface; (2) beginning June 4, 1951, arrow on sandstone slab East side even with land surface.

Apr. 8 1951	14·90				
June 4, 1951	9·39	Oct. 24, 1951	12·10	May, 15, 1952	12·69

No. 25P. Sava Mallah. Dug 5 by 9 feet across and 45 feet deep, two borings each 100 feet deep in bottom. Water from Upper Bhuj sandstone. Measuring point, arrow on sandstone slab centre, East side 1·0 foot above land surface; altitude 232·26 feet.

Apr. 9, 1951	22·15	Oct. 24, 1951	29·28	May 15, 1952	34·20*

o. 26P. Owner unknown. Irrigation well, dug 23 feet deep. Measuring point, arrow on sandstone slab, South side of well, 2·0 feet above land surface altitude 224·57 feet.

Apr. 9, 1951	14·90				
June 4, 1951	15·81	Oct. 24, 1951	15·68	May, 15, 1952	18·38

* *Pumping water level*

APPENDIX 12—*contd.*

No. 27P. Nanji Bhimji. Irrigation well, dug 8 by 12 feet across and 29 feet deep. Water from Deccan trap. Measuring point, arrow at middle sandstone slab, East side, 2·0 feet above land surface ; altitude 211·34 feet.

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet,
Apr. 11, 1951 .	10·78				
June 4, 1951 .	11·13	Oct. 24, 1951 .	10·98	May 15, 1952 .	12·17

No. 28P. Hira Rura. Irrigation well, dug 9 feet square and 24 feet deep. Water from Deccan traps. Measuring point, arrow on sand stone slab Northeast corner, 3·0 feet above land surface ; altitude 220·78 feet.

Apr. 11, 1951 .	17·22				
June 4, 1951 .	21·03*	Oct. 24, 1951 .	17·59	May 15, 1952 .	20·86

No. S32. Owner unknown. Unused well, dug 10 by 11 feet across and 43 feet deep. Water from Upper Bhuj sandstone. Measuring point arrow on projecting sandstone slab East side, 2·0 feet above land surface ; altitude 234·74 feet.

Apr. 22, 1951 .	34·48				
June 6, 1951 .	35·60	Nov. 12, 1951 .	37·34	May 12, 1952 .	40·29

No. S34. Owner unknown. Unused well, dug 11 feet square and 63 feet deep. Water from Upper Bhuj sandstones. Measuring point, arrow on timber, 0·34 foot above top of sandstone curb, 2·0 feet above land surface altitude 254·66 feet.

Apr. 22, 1951 .	52·89				
June 6, 1951 .	54·66	Nov. 11, 1951 .	57·27	May 12, 1952 .	60·74

No. S40. Owner unknown. Irrigation well, dug 10 by 22 feet across and 67 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on lip of projecting sandstone slab, South side, even with land surface; altitude 257·50 feet.

Apr. 24, 1951 .	61·80				
June 6, 1951 .	57·82	Nov. 12, 1951 .	60·30	May 12, 1952 .	68·66

* *Pumping water level.*

APPENDIX 12—*contd.*

No. S45. Temple. Domestic well, dug 7 feet square and 28 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on lip of projecting sandstone slab, West side, 3·0 feet above land surface ; altitude 206·01 feet.

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
Apr. 26, 1951 .	19·94				
June 26, 1951 .	21.40	Nov. 11, 1951 .	23·33	May 12, 1952 .	27·69

No. S53. Owner unknown. Stock well, dug 7 by 11 feet across and 61 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on projecting sandstone slab, North side, even with land surface ; altitude 261·40 feet.

Apr. 29, 1951 .	56·88				
June 6, 1951 .	56·79	Nov. 12, 1951 .	57·02	May 12, 1952 .	59.28

No. 3. Owner unknown. Unused dug well, dimension 8 by 18 feet and 24 feet deep. Water from Upper Bhuj sandstone. Measuring point (1) lip of sandstone slab, east side, 0·5 foot aove land surface ; altitude ; 215·02 feet. Measuring point (2) top edge of floor of recorder shelter altitude 215·14 feet. Measurement prior to March 11, 1952 are the highest daily water level, in feet, below m.p. (2) and thereafter by tape from m.p. (1).

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
1951		1951		1951	
Mar. 9	12·13*	Mar. 26	9·05	Apr. 11	99·10
Mar. 10	10·54	Mar. 27	9·05	Apr. 12	9·07
Mar. 11	9·94	Mar. 28	9·05	Apr. 13	9·10
Mar. 12	9·78	Mar. 29	9·03	Apr. 14	9·12
Mar. 13	9·60	Mar. 30	9·04	Apr. 15	9·21
Mar. 14	9·46	Mar. 31	9·02	Apr. 16	9·25
Mar. 15	9·41			Apr. 17	9·27
Mar. 16	9·34	Apr. 1	9·02	Apr. 18	9·32
Mar. 17	9·29	Apr. 2	8·98	Apr. 19	9·31
Mar. 18	9·32	Apr. 3	8·99	Apr. 20	9·33
Mar. 19	9·24	Apr. 4	8·99	Apr. 24	9·23
Mar. 20	9·18	Apr. 5	8·98	Apr. 25	9·23
Mar. 21	9·15	Apr. 6	8·98	Apr. 26	9·24
Mar. 22	9·14	Apr. 7	9·01	Apr. 27	9.25
Mar. 23	9·11	Apr. 8	9·07	May 1	9·38
Mar. 24	9·07	Apr. 9	9·16	May 2	9.43
Mar. 25	9·05	Apr. 10	9·13	May 3	9·51

* *Water-stage-recorder installed.*

APPENDIX 12—*contd.*

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
1951		1951		1951	
May 4	9·44	July 11	9·36	Aug. 30	8·42
May 5	9·40	July 12	9·37	Aug. 31	8·44
May 6	9·37	July 13	9·37		
May 7	9.39	July 14	9·37	Sept. 1	8·46
May 8	9·41	July 15	9·38	Sept. 2	8·47
May 9	9·42	July 16	9·38	Sept. 3	8·47
May 10	9·45	July 17	9·41	Sept. 4	8·53
May 11	9.47	July 18	9·43	Sept. 5	8·58
May 12	9·48	July 19	9·42	Sept. 6	8·62
May 13	9.48	July 20	9·43	Sept. 7	8·72
May 14	9·61	July 21	9·42	Sept. 8	8·74
May 15	9.67	July 22	9·40	Sept. 9	8·78
May 16	9·70	July 23	9·39	Sept. 10	8·82
May 17	9·82	July 24	9·37	Sept. 11	8·84
May 18	9·73	July 25	9·40	Sept. 12	8·87
May 19	9·70	July 26	9·32	Sept. 13	8·89
May 20	9·67	July 27	8·60	Sept. 14	8·90
May 21	9·74	July 28	8·07	Sept. 15	8·88
May 22	9·78	July 29	8·06	Sept. 16	8·90
May 29	9·79	July 30	8·11	Sept. 17	8·93
May 30	9·76	July 31	8·16	Sept. 18	8·92
May 31	9·73			Sept. 19	8·91
				Sept. 20	8·90
June 1	9·69	Aug. 1	8·21	Sept. 21	8·94
June 2	9·66	Aug. 2	8·27	Sept. 22	8·98
June 3	9·62	Aug. 3	8·32	Sept. 23	9·01
June 4	9·65	Aug. 4	8·33	Sept. 24	9·04
June 5	9·63	Aug. 5	8·37	Sept. 25	9·06
June 6	9·65	Aug. 6	8·37	Sept. 26	9·08
June 7	9·66	Aug. 7	8·39	Sept. 27	9·12
June 8	9·66	Aug. 8	8·36	Sept. 28	9·16
June 9	9·65	Aug. 9	8·33	Sept. 29	9·21
June 10	9·65	Aug. 10	8·32	Sept. 30	9·26
June 12	9·68	Aug. 11	8·30		
June 13	9·67	Aug. 12	8·30		
June 14	9·64	Aug. 13	7·97		
June 21	9·64	Aug. 14	7·91	Oct. 1	9·29
June 22	9·64	Aug. 15	7·93	Oct. 2	9·29
June 23	9·63	Aug. 16	7·99	Oct. 3	9·31
June 25	9·59	Aug. 17	8·01	Oct. 4	9·33
June 26	9·60	Aug. 18	8·06	Oct. 5	9·35
June 27	9·60	Aug. 19	8·09	Oct. 6	9·37
June 28	9·48	Aug. 20	8·11	Oct. 7	9·38
June 29	9·33	Aug. 21	8·14	Oct. 8	9·38
June 30	9·29	Aug. 22	8·17	Oct. 9	9·40
		Aug. 23	8·20	Oct. 10	9·41
July 1	9·28	Aug. 24	8·22	Oct. 11	9·43
July 2	9·28	Aug. 25	8·23	Oct. 12	9·48
July 7	9·33	Aug. 26	8·28	Oct. 13	9·49
July 8	9·34	Aug. 27	8·30	Oct. 14	9·49
July 9	9·36	Aug. 28	8·34	Oct. 15	9·48
July 10	9·35	Aug. 29	8·38	Oct. 16	9·49

APPENDIX 12—*contd.*

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
1951		1951		1952	
Oct. 17	9·50	Dec. 5	10·24	Jan. 22	10·50
Oct. 18	9·49	Dec. 6	10·22	Jan. 23	10·51
Oct. 19	9·48	Dec. 7	10·19	Jan. 24	10·55
Oct. 20	9·48	Dec. 8	10·17	Jan. 25	10·55
Oct. 21	9·46	Dec. 9	10·16	Jan. 26	10·58
Oct. 22	9·48	Dec. 10	10·15	Jan. 27	10·57
Oct. 23	9·47	Dec. 11	10·14	Jan. 28	10·60
Oct. 24	9·45	Dec. 12	10·14	Jan. 29	10·67
Oct. 25	9·49	Dec. 13	10·20	Jan. 30	10·65
Oct. 26	9·51	Dec. 14	10·20	Jan. 31	10·67
Oct. 27	9·53	Dec. 15	10·23		
Oct. 28	9·62	Dec. 16	10·22	Feb. 1	10·68
Oct. 29	9·63	Dec. 17	10·21	Feb. 2	10·70
Oct. 30	10·03	Dec. 18	10·21	Feb. 3	10·71
Oct. 31	9·84	Dec. 19	10·21	Feb. 4	10·71
		Dec. 20	10·20	Feb. 5	10·64
		Dec. 21	10·21	Feb. 6	10·61
Nov. 1	9·76	Dec. 22	10·21	Feb. 7	10·61
Nov. 2	9·75	Dec. 23	10·20	Feb. 8	10·62
Nov. 3	9·75	Dec. 24	10·20	Feb. 9	10·62
Nov. 4	9·75	Dec. 25	10·24	Feb. 10	10·63
Nov. 5	9·75	Dec. 26	10·26	Feb. 11	10·63
Nov. 6	9·87	Dec. 27	10·28	Feb. 12	10·63
Nov. 7	9·86	Dec. 28	10·21	Feb. 13	10·66
Nov. 8	9·91	Dec. 29	10·16	Feb. 14	10·69
Nov. 9	9·98	Dec. 30	10·14	Feb. 15	10·69
Nov. 10	10·01	Dec. 31	10·16	Feb. 16	10·70
Nov. 11	10·05			Feb. 17	10·70
Nov. 12	10·06			Feb. 18	10·71
Nov. 13	10·10	1952		Feb. 19	10·73
Nov. 14	10·16			Feb. 20	10·76
Nov. 15	10·20	Jan. 1	10·17	Feb. 21	10·79
Nov. 16	10·16	Jan. 2	10·25	Feb. 22	10·79
Nov. 17	10·15	Jan. 3	10·30	Feb. 23	10·80
Nov. 18	10·10	Jan. 4	10·28	Feb. 24	10·78
Nov. 19	10·03	Jan. 5	10·30	Feb. 25	10·80
Nov. 20	10·01	Jan. 6	10·28	Feb. 26	10·82
Nov. 21	10·05	Jan. 7	10·33	Feb. 27	10·84
Nov. 22	10·11	Jan. 8	10·33	Feb. 28	10·85
Nov. 23	10·14	Jan. 9	10·35	Feb. 29	10·87
Nov. 24	10·14	Jan 10	10·41		
Nov. 25	10·19	Jan. 11	10·40	Mar. 1	10·87
Nov. 26	10·19	Jan. 12	10·41	Mar. 2	10·89
Nov. 27	10·21	Jan. 13	10·42	Mar. 3	10·92
Nov. 28	10·22	Jan. 14	10·41	Mar. 4	10·90
Nov. 29	10·22	Jan. 15	10·42	Mar. 5	10·90
Nov. 30	10·22	Jan. 16	10·42	Mar. 6	10·89
		Jan. 17	10·46	Mar. 7	10·89
Dec. 1	10·23	Jan. 18	10·47	Mar. 8	10·89
Dec. 2	10·19	Jan. 19	10·47	Mar. 9	10·92
Dec. 3	10·22	Jan. 20	10·47	Mar. 10	10·92
Dec. 4	10·22	Jan. 21	10·48	Mar. 11	10·93*

* *Water-stage recorder removed.*

APPENDIX 12—*contd.*

Date	Depth to water (feet)
1952	
May 25	11·88
June 1	12·10
June 8	12·20
June 15	12·10
June 22	12·00
June 29	11·84
July 6	11·94
July 13	11·72
July 20	9·90
July 27	8·48
Aug. 3	8·10
Aug. 10	7·49
Aug. 17	7·10
Aug. 24	7·59
Aug. 31	8·04
Sept. 7	8·34
Sept. 12	8·45
Sept. 19	8·72
Sept. 26	9·00
Oct. 4	9·39
Oct. 10	9·34
Oct. 17	9·70
Oct. 24	9·78
Oct. 31	9·92
Nov. 7	10·08
Nov. 14	10·30
Nov. 21	10·32
Nov. 28	10·38
Dec. 5	10·68
Dec. 12	10·58
Dec. 19	10·62
Dec. 26	10·68
1953	
Jan. 2	10·70
Jan. 9	9·98
Jan. 16	10·24
Jan. 23	10·35
Jan. 30	10·50
Feb. 6	10·58
Feb. 13	10·75
1653	
Feb. 20	10·89
Feb. 27	11·00
Mar. 6	11·09
Mar. 13	11·18
Mar. 20	11·35
Mar. 27	11·53
Apr. 3	11·60
Apr. 10	11·75
Apr. 17	11·87
Apr. 24	12·08
May 1	12·24
May 8	12·35
May 15	12·38
May 22	12·48
May 29	12·56
June 5	12·74
June 12	12·80
June 19	12·85
June 26	12·70
July 3	12·36
July 10	12·32
July 17	12·42
July 24	12·58
July 31	12·58
Aug. 7	9·42
Aug. 14	9·40
Aug. 21	6·53
Aug. 28	6·20
Sept. 4	7·03
Sept. 11	6·75
Sept. 18	7·38
Sept. 29	7·64
Oct. 2	8·05
Oct. 9	8·40
1953	
Oct. 16	8·66
Oct. 23	9·00
Oct. 30	9·18
Nov. 6	9·29
Nov. 13	9·48
Nov. 20	9·53
Nov. 27	9·76
Dec. 4	9.82
Dec. 11	10·02
Dec. 18	10·17
Dec. 25	10·30
1954	
Jan. 1	10·36
Jan. 8	10·43
Jan. 15	10·57
Jan. 22	10·63
Jan. 29	10·84
Feb. 5	10·90
Feb. 12	11·13
Feb. 19	11·20
Feb. 26	11·35
Mar. 5	11·48
Mar. 12	11·55
Mar. 19	11·69
Mar. 26	11·67
Apr. 2	11·80
Apr. 9	12·00
Apr. 16	12·22
Apr. 23	12·50
Apr. 30	12·70
May 5	12·82
May 14	12·98
May 21	13·30
May 28	13·45
June 4	13·30

APPENDIX 12—*contd.*

No. 4. Dioji. Unused well, dug 8 by 5 feet across and 41 feet deep. Water from Upper Bhuj sandstone. Measuring point (1) lip of sandstone slab, south side, even with land surface; altitude 268·93 feet. Measuring point (2) top edge of floor of recorder shelter; altitude 269·60 feet.

Highest daily water level, in feet, below measuring point (2), 1951.
(From automatic water level recorder)

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
1951		1951		1951	
Mar. 21	22·71†	May 15	23·52	July 15	23·48
Mar. 22	22·37	May 16	23·51	July 16	23·84
Mar. 23	22·46	May 17	23·62	July 17	23·93
Mar. 28	22·35	May 18	23·84	July 18	24·08
Mar. 29	22·08	May 19	23·90	July 19	24·07
		May 20	23·88	July 20	24·03
Apr. 2	22·03	May 21	23·95	July 21	23·77
Apr. 3	21·97	May 22	24·04	July 22	23·76
Apr. 4	21·83	May 23	24·11	July 23	23·88
Apr. 5	21·72	May 24	24·00	July 24	23·67
Apr. 6	21·67	May 25	24·02	July 25	23·68
Apr. 7	21·56	May 26	23·97	July 26	23·49
Apr. 8	21·52	May 27	24·15	July 27	23·30
Apr. 9	21·55	May 28	24·35	July 28	23·15
Apr. 10	21·30	May 29	24·28	July 29	22·19
Apr. 14	21·40	May 30	24·30	July 30	22·84
Apr. 15	21·42	May 31	23·84	July 31	22·67
Apr. 16	21·57				
Apr. 17	22·14	June 1	23·73	Aug. 1	22·63
Apr. 18	22·22	June 2	24·30	Aug. 2	22·54
Apr. 19	22·15	June 3	24·54	Aug. 3	22·54
Apr. 20	22·13	June 4	23·92	Aug. 4	22·42
Apr. 21	22·01	June 5	23·57	Aug. 5	22·31
Apr. 22	21·97	June 6	24·21	Aug. 6	22·23
Apr. 23	22·01	June 7	24·41	Aug. 7	22·16
Apr. 24	22·24	June 8	24·53	Aug. 8	22·02
Apr. 25	22·13	June 9	24·53	Aug. 9	21·99
Apr. 26	22·38	June 10	24·68	Aug. 10	21·89
Apr. 27	22·35	June 11	24·50	Aug. 11	21·86
Apr. 28	22·40	June 12	24·61	Aug. 12	21·82
Apr. 29	22·53	June 13	24·36	Aug. 13	21·74
Apr. 30	22·53	June 14	24·35	Aug. 14	21·61
		June 15	24·40	Aug. 15	21·55
May 1	22·56	June 16	23·93	Aug. 16	21·59
May 2	22·68	June 17	24·28	Aug. 17	21·53
May 3	22·53	June 18	24·32	Aug. 18	21·44
May 4	22·42	June 19	24·33	Aug. 19	21·42
May 9	22·98	June 20	24·33	Aug. 20	21·41
May 10	23·05	June 21	24·60*	Aug. 21	21·45
May 11	23·18			Aug. 22	21·53
May 12	23·43	July 12	22·87**	Aug. 23	21·52
May 13	23·62	July 13	22·83	Aug. 24	21·35
May 14	23·66	July 14	22·96	Aug. 25	21·33

†*Recorder installed March 21, 1951*

**Recorder removed June 21, 1951.*

***Recorder replaced July 12, 1951.*

APPENDIX 12—*contd.*

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
1951		1951		1951	
Aug. 26	21·78	Oct. 18	23·67	Dec. 13	25·13
Aug. 27	22·08	Oct. 23	23·95	Dec. 20	25·34
Aug. 28	22·38	Oct. 24	24·01	Dec. 21	25·20
Aug. 29	22·59	Oct. 25	24·25	Dec. 22	25·19
Aug. 30	22·63	Oct. 26	24·35	Dec. 23	25·18
Aug. 31	22·71	Oct. 27	24·13	Dec. 24	25·08
		Oct. 28	24·14	Dec. 25	25·10
Sept. 1	22·58	Oct. 29	24·07	Dec. 26	25·05
Sept. 2	22·50	Oct. 30	24·47	Dec. 27	25·16
Sept. 3	22·58			Dec. 28	25·05
Sept. 4	22·75	Nov. 1	24·14	Dec. 29	24·93
Sept. 5	22·90	Nov. 2	24·44	Dec. 30	25·09
Sept. 6	23·10	Nov. 3	24·63	Dec. 31	25·26
Sept. 7	23·12	Nov. 4	24·65		
Sept. 8	23·26	Nov. 5	24·67		
Sept. 9	23·30	Nov. 6	24·63		
Sept. 10	23·32	Nov. 7	24·55	1952	
Sept. 11	23·25	Nov. 9	24·93		
Sept. 12	23·45	Nov. 10	24·80	Jan. 1	25·23
Sept. 13	23·63	Nov. 11	24·75	Jan. 2	25·13
Sept. 14	23·84	Nov. 12	24·75	Jan. 4	25·10
Sept. 15	23·86	Nov. 13	24·82	Jan. 5	25·18
Sept. 16	23·66	Nov. 14	24·75	Jan. 6	25·20
Sept. 17	23·54	Nov. 15	24·62	Jan. 7	25·37
Sept. 18	23·55	Nov. 16	24·64	Jan. 8	25·37
Sept. 19	23·45	Nov. 17	24·73	Jan. 9	25·46
Sept. 20	23·74	Nov. 18	24·56	Jan. 10	25·48
Sept. 21	23·76	Nov. 19	24·28	Jan. 11	25·41
Sept. 22	23·77	Nov. 20	24·17	Jan. 12	25·46
Sept. 23	23·90	Nov. 21	24·11	Jan. 13	25·62
Sept. 24	23·97	Nov. 22	24·14	Jan. 14	25·38
Sept. 25	24·17	Nov. 23	24·45	Jan. 15	25·26
Sept. 26	24·17	Nov. 24	24·52	Jan. 16	25·34
Sept. 27	24·30	Nov. 25	24·63	Jan. 17	25·40
Sept. 28	24·40	Nov. 26	24·77	Jan. 18	25·48
Sept. 29	24·44	Nov. 27	24·72	Jan. 19	25·45
Sept. 30	24·50	Nov. 28	24·65	Jan. 20	25·38
		Nov. 29	24·57	Jan. 21	25·45
Oct. 1	24·32	Nov. 30	24·53	Jan. 22	25·47
Oct. 2	24·26			Jan. 23	25·50
Oct. 3	24·45	Dec. 1	24·45	Jan. 24	25·56
Oct. 4	24·63	Dec. 2	24·58	Jan. 25	25·49
Oct. 5	24·68	Dec. 3	24·81	Jan. 31	25·46
Oct. 6	24·78	Dec. 4	24·98		
Oct. 7	24·67	Dec. 5	25·09	Feb. 1	25·58
Oct. 11	24·07	Dec. 6	25·00	Feb. 2	25·60
Oct. 12	23·89	Dec. 7	24·87	Feb. 3	25·50
Oct. 13	23·85	Dec. 8	24·84	Feb. 4	25·31
Oct. 14	23·81	Dec. 9	24·73	Feb. 5	25·20
Oct. 15	23·84	Dec. 10	24·73	Feb. 6	25·32
Oct. 16	23·75	Dec. 11	24·93	Feb. 7	25·30
Oct. 17	23·73	Dec. 12	25·15	Feb. 8	25·48

APPENDIX 12—*contd.*

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
1952		1952		1952	
Feb. 9	25·56	Feb. 23	25·90	Mar. 12	25·86
Feb. 10	25·77	Feb. 24	25·85	Mar. 13	25·75
Feb. 11	25·85	Feb. 25	25·83	Mar. 14	25.73
Feb. 12	25·80	Feb. 26	25·64	Mar. 15	25·78
Feb. 13	25·65			Mar. 16	25·84
Feb. 14	25·63			Mar. 17	25·86
Feb. 15	25·76			Mar. 18	25·80
Feb. 16	25·95	Mar. 5	26·23	Mar. 19	25·92
Feb. 17	25·75	Mar. 6	25·98	Mar. 20	25·86
Feb. 18	25·67	Mar. 7	26·00	Mar. 21	25·63
Feb. 19	25·80	Mar. 8	25·74	Mar. 22	25·50
Feb. 20	25·71	Mar. 9	25.82	Mar. 23	25·65
Feb. 21	25·75	Mar. 10	25·98	Mar. 24	25·64
Feb. 22	25·95	Mar. 11	25·78	Mar. 25	25·60*

No. 5. Khemji Dosani. Unused well, dug 9 by 12 feet and 52 feet deep. Water from Upper Bhuj sandstone. Measuring point, lip of sandstone slab east side, 2·0 feet above land surface; altitude 243·57 feet.

Feb. 24, 1951 .	26·37	Nov. 11, 1951 .	32·10	May 14, 1952 .	35·23
June 5, 1951 .	29·32				

No. 6. Owner unknown. Unused well, dug 14 by 10 feet and 59 feet deep. Water from Upper Bhuj sandstone. Measuring point (1) lip of sandstone slab east side, even with land surface; altitude 237·98 feet. Measuring point (2) top edge of floor of recorder shelter; altitude 238·39 feet.

1951		1951		1951	
Feb. 24	35·99*	May 27	38·13	June 8	38·46
		May 28	38·19	June 9	38·48
May 1	37·34*	May 29	38·23	June 10	38·51
May 8	37·49*	May 30	38·24	June 11	38·54
May 15	37·72*	May 31	38·24	June 12	38·59
May 19	37·87**			June 13	38·62
May 20	37·90	June 1	38·28	June 14	38·60
May 21	37·93	June 2	38·34	June 15	38·62
May 22	37·96	June 3	38·39	June 16	38·64
May 23	37·99	June 4	38·31	June 17	38·66
May 24	38·04	June 5	38·32	June 18	38·68
May 25	38·07	June 6	38·40	June 19	38·70
May 26	38·10	June 7	38·46	June 20	38·74

* *Tape measurement adjusted to MP (2.)*
** *Recorder installed May 19,1951.*

APPENDIX 12—*contd.*

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
1951		1951		1951	
June 21	38·73	Aug. 7	38·94	Sept. 19	39·79
June 22	38·79	Aug. 8	38·88	Sept. 20	39·83
June 23	38·80	Aug. 9	38·79	Sept. 21	39·85
June 24	38·79	Aug. 10	38·73	Sept. 22	39·88
June 25	38·83	Aug. 11	38·73	Sept. 23	39·91
June 26	38·87	Aug. 12	38·72	Sept. 24	39·93
June 27	38·87	Aug. 13	38·66	Sept. 25	39·98
June 28	38·82	Aug. 14	38·58	Sept. 26	40·02
June 29	38·71	Aug. 15	38·57	Sept. 27	40·02
June 30	38·65	Aug. 16	38·55	Sept. 28	40·06
		Aug. 17	38·68	Sept. 29	40·09
July 5	38·67	Aug. 18	38·71	Sept. 30	40·12
July 6	38·72	Aug. 19	38·78		
July 7	38·73	Aug. 20	38·79		
July 8	38·72	Aug. 21	38·84		
July 9	38·73	Aug. 22	38·89	Oct. 1	40·14
July 10	38·78	Aug. 23	38·95	Oct. 2	40·16
July 11	38·80	Aug. 24	38·85	Oct. 3	40·21
July 12	38·81	Aug. 25	38·84	Oct. 4	40·27
July 13	38·82	Aug. 26	38·93	Oct. 5	40·31
July 14	38·90	Aug. 27	39·02	Oct. 6	40·35
July 15	38·93	Aug. 28	39·07	Oct. 7	40·41
July 16	38·96	Aug. 29	39·09	Oct. 8	40·44
July 17	38·99	Aug. 30	39·12	Oct. 9	40·46
July 18	39·01	Aug. 31	39·19	Oct. 10	40·48
July 19	39·00			Oct. 11	40·49
July 20	39·02			Oct. 12	40·49
July 21	39·03			Oct. 13	40·50
July 22	39·03	Sept. 1	39·14	Oct. 14	40·48
July 23	39·07	Sept. 2	39·12	Oct. 15	40·48
July 24	39·10	Sept. 3	39·20	Oct. 16	40·52
July 25	39·11	Sept. 4	39·29	Oct. 17	40·55
July 26	39·17	Sept. 5	39·28	Oct. 18	40·56
July 27	39·07	Sept. 6	39·34	Oct. 19	40·58
July 28	39·03	Sept. 7	39·37	Oct. 20	40·58
July 29	38·95	Sept. 8	39·42	Oct. 21	40·59
July 30	38·91	Sept. 9	39·47	Oct. 22	40·61
July 31	38·90	Sept. 10	39·51	Oct. 23	40·62
		Sept. 11	39·55	Oct. 24	40·62
		Sept. 12	39·56	Oct. 25	40·65
Aug. 1	38·91	Sept. 13	39·57	Oct. 26	40·66
Aug. 2	38·94	Sept. 14	39·61	Oct. 27	40·66
Aug. 3	38·90	Sept. 15	39·67	Oct. 28	40·68
Aug. 4	38·92	Sept. 16	39·69	Oct. 29	40·73
Aug. 5	38·94	Sept. 17	39·71	Oct. 30	40·73
Aug. 6	38·96	Sept. 18	39·76	Oct. 31	40·71*

* *Recorder removed October 31, 1951.*

APPENDIX 12—*contd.*

No. 7. Toll House. Public well, dug 5 by 7 feet across and 47 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on edge of curb south side even with land surface ; altitude 244·58 feet.

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
Feb. 25 1951 .	41·64			Jan. 16 1952 .	45·27
June 1 1951 .	42·80	Sept. 16 1951 .	43·61	Feb. 15 1952 .	45·63
June 22 1951 .	43·13	Oct. 28 1951 .	44·13	Mar. 24 1952 .	46·48
July 20 1951 .	43·39	Nov. 16 1951 .	44·40	Apr. 18 1952 .	47·49
Aug. 14 1951 .	43·48	Dec. 12 1951 .	44·62	May 12 1952 .	47·19

No. 9. Owner unknown. Public well, dug 85 feet deep. Water from Lower Bhuj sandstone. Measuring point, arrow on top of curb north side, even with land surface; altitude 337·74 feet.

Feb. 25 1951 .	70·70			Jan. 16 1952 .	71·32
June 1 1951 .	74·20	Sept. 16 1951 .	70·90	Feb. 15 1952 .	71·34
June 22 1951 .	72·84	Oct. 28 1951 .	71·05	Mar. 24 1952 .	71·49
July 20 1951 .	74·41	Nov. 16 1951 .	71·03	Apr. 18 1952 .	71·58
Aug. 14 1951 .	70·77	Dec. 12 1951 .	71·18	May 13 1952 .	71·64

No. 17. Shiva Shrine. Domestic well, dug 5 feet in diameter and 31 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on top of curb north side, even with land surface ; altitude 246·27 feet.

Feb. 27 1951 .	18·06	Sept. 6 1951 .	20·34	Jan. 3 1952 .	23·10
		Sept. 13 1951 .	20·67	Jan. 9 1952 .	23·27
May 1 1951 .	19·58	Sept. 20 1951 .	20·96	Jan. 16 1952 .	22·76
May 8 1951 .	19·72	Sept. 29 1951 .	20·60	Jan. 23 1952 .	23·06
May 15 1951 .	19·85			Jan. 30 1952 .	23·00
May 22 1951 .	19·93				
May 29 1951 .	19·91	Oct. 4 1951 .	21·03	Feb. 6 1952 .	23·04
		Oct. 11 1951 .	21·23	Feb. 13 1952 .	23·41
June 1 1951 .	19·97	Cot. 18 1951 .	21·12	Feb. 20 1952 .	23·27
June 5 1951 .	19·97	Oct. 26 1951 .	21·22	Feb. 26 1952 .	23·51
June 12 1951 .	20·79	Oct. 31 1951 .	21·59		
June 19 1951 .	21·83			Mar. 4 1952 .	23·70
June 26 1951 .	20·58			Mar. 11 1952 .	23·65
		Nov. 8 1951 .	21·67	Mar. 18 1952 .	23·65
July 3 1951 .	20·35	Nov. 11 1951 .	21·59	Mar. 25 1952 .	23·87
July 12 1951 .	20·58	Nov. 15 1951 .	21·64		
July 19 1951 .	20·58	Nov. 22 1951 .	21·68	Apr. 1 1952 .	24·36
July 26 1951 .	20·60	Nov. 29 1951 .	21·85	Apr. 8 1952 .	23·95
				Apr. 15 1952 .	23·78
Aug. 2 1951 .	18·71			Apr. 22 1952 .	24·04
Aug. 9 1951 .	19·95	Dec. 6 1951 .	22·16	Apr. 29 1952 .	24·12
Aug. 16 1951 .	19·44	Dec. 13 1951 .	22·19		
Aug. 23 1951 .	20·09	Dec. 20 1951 .	22·28	May 11 1952 .	24·89
Aug. 30 1951 .	20·20	Dec. 27 1951 .	22·49	May 14 1952 .	24·29

APPENDIX 12—*contd.*

No. 18. Dalu Dhanji. Irrigation well, dug 12 by 7 feet across and 53 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on lip of sandstone slab east side, 2·0 feet above land surface ; altitude 262·22 feet.

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
Feb. 27 1951	39·80				
June 7 1951	36·09	Nov. 11 1951	39·32	May 14 1952	43·94

No. 19. Kuarji Maoji. Irrigation well, dug 10 by 8 feet across and 34 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on lip of sandstone slab southeast corner, at land surface ; altitude 224·83 feet.

Feb. 28 1951	17·50				
June 4 1951	19·50	Oct. 24 1951	18·50	May 15	24·94

No. 20. Khema Anda. Irrigation well, dug 10 by 7 feet across and 44 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on sandstone slab northeast corner, at land surface ; altitude 232·17 feet.

Feb. 28 1951	29·10				
June 2 1951	25·47	Oct. 24 1951	28·77	May 16 1952	28·09

No. 23. Ruined temple. Unused well, dug 7 feet square and 41 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on lip of projecting sandstone slab, north side, at land surface ; altitude 288·69 feet.

1951		1951		1951	
March 1	29·80	Aug. 2	31·74	Nov. 8	33·05
		Aug. 9	31·82	Nov. 12	33.10
May 1	30·50	Aug· 16	31.90	Nov. 15	33·14
May 8	30·59	Aug. 23	31·99	Nov. 22	33·24
May 15	30·60	Aug. 30	32·13	Nov. 29	33·39
May 22	30·78				
May 29	30·84			Dec. 6	33·47
		Sept. 6	32·19	Dec. 13	33·57
June 5	39.91	Sept. 13	32·30	Dec. 20	33·65
June 12	30·01	Sept. 20	32.40	Dec. 27	33·69
June 19	31·12	Sept. 29	32·53		
June 26	31·24				
		Oct. 4	32·62		
July 3	31·34	Oct. 11	32·70	1952	
July 12	31·41	Oct. 18	32·75		
July 19	31·12	Oct. 23	32·86	Jan. 3	33·86
July 26	31·24	Oct. 31	32.95	Jan. 9	33·92

APPENDIX 12—*contd.*

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
1952		1952		1952	
Jan. 16	34·03	Feb. 20	34·44	Apr. 1	34·98
Jan. 23	34·08	Feb. 26	34·49	Apr. 8	35·05
Jan. 30	34·14			Apr. 15	35·13
				Apr. 24	35·24
		Mar. 4	34·60	Apr. 29	35·33
		Mar. 11	34·69		
Feb. 6	34·23	Mar. 18	34·78	May 11	35.07
Feb. 13	34·32	Mar. 25	34·86	May 14	35·42

No. 24. Babu Yadaugi. Irrigation well, dug 7 by 9 feet across and 44 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on lip of sandstone slab east side, at land surface ; altitude 281·68 feet.

Mar. 1 1951	31.35				
June 9 1951	33·83	Nov. 12 1951	33·85	May 14 1952	35·42

No. 26. Temple. Unused well, dug 6 feet square and 37 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on top of sandstone curb, south side, at land surface ; altitude 265·96 feet.

1951		1951		1952	
Mar. 1	29·85	Sept. 6	30·43	Jan. 3	31·66
		Sept. 13	30·55	Jan. 9	31·70
May* 1	29·93	Sept. 20	30·67	Jan. 16	31·78
May 8	29·98	Sept. 29	30·77	Jan. 23	31·81
May 15	30·04			Jan. 30	31·90
May 22	30·13				
May 29	30·19	Oct. 4	30·91	Feb. 6	31·96
		Oct. 11	30·04	Feb. 13	32·02
June 5	30·24	Oct. 18	30·92	Feb. 20	31·22
June 12	30·31	Oct. 23	30·97	Feb. 26	32·16
June 19	30·37	Oct. 31	31·02		
June 26	30·43			Mar. 4	32·22
				Mar. 11	32·30
July 3	30·37	Nov. 8	31·09	Mar. 18	32·39
July 12	30·32	Nov. 12	31·12	Mar. 25	32·41
July 19	30·38	Nov. 15	31·15	Apr. 1	32·46
July 26	30.43	Nov. 22	31·20	Apr. 8	32·53
		Nov. 29	31·33	Apr. 15	32·57
Aug. 2	30·42			Apr. 24	32·69
Aug. 9	30·33			Apr. 29	32·73
Aug. 16	30·31	Dec. 6	31·36		
Aug. 22	30·28	Dec. 13	31·40	May 11	32·90
Aug. 30	30·44	Dec. 20	31·50	May 14	32·90
		Dec. 27	31·59		

APPENDIX 12—*contd.*

No. 28. Owner unknown. Irrigation well, dug 11 by 12 feet across and 41 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on projecting sandstone slab, west side, 2·0 feet above land surface ; altitude 231·34 feet.

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
Apr. 9 1951	31·78				
June 6 1951	32·64	Nov. 13 1951	34·35	May 12 1952	36·86

No. 40. Owner unknown. Public well, dug 7 feet in diameter and 18 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on top of sandstone curb west side, 1·7 feet above land surface ; altitude 222·87 feet.

Mar. 5 1951	9·95				
June 3 1951	11·78	Oct. 23 1951	10·93	May 15 1952	15·14

No. 41. Owner unknown. Unused well, dug 7 by 9 feet across and 33 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on trap cobble, north side, at land surface ; altitude 219·79 feet.

Mar. 5 1951	10·73				
June 3 1951	12·58	Oct. 24 1951	11·58	May 15 1952	19·78

No. 42. Owner unknown. Irrigation well, dug 10 by 18 feet across and 26 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on sandstone slab, centre of east side, at land surface ; altitude 231·39 feet.

Mar. 5 1951	10·73				
June 3 1951	16·02	Oct. 24 1951	15·63	May 15 1952	19·53

No. 46. Owner unknown. Irrigation well, dug 8 by 7 feet across and 41 feet deep. Water from Deccan trap. Measuring point, arrow on sandstone slab, north side, 1·0 foot above land surface ; altitude 199·47 feet.

Mar. 8 1951	12·42				
June 4 1951	17·06	Oct. 24 1951	13·10	May 14 1952	14·54

APPENDIX 12—*contd.*

No. 47. Hamir Malla Koli. Irrigation well, dug 13 by 8 feet across and 34 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on sandstone slab, east side, 1·0 foot above land surface ; altitude 225·09 feet.

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
Mar. 12 1951	17·38				
June 4 1951	18·37	Oct. 24 1951	20·40	May 15 1952	25·09

No. 48. Owner unknown. Unused well, dug 13 by 8 feet across and 38 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on sandstone slab ; centre of east side, 3·0 feet above land surface ; altitude 233·53 feet.

Mar. 13 1951	16·85				
June 3 1951	18·13	Oct. 24 1951	17·68	May 15 1952	21·54

No. 49. Owner unknown. Unused well, dug 29 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on sandstone slab centre of north side, 2·0 feet above land surface ; altitude 237·89 feet.

Mar. 13 1951	23·50				
June 3 1951	21·70	Oct. 24 1951	21·49	May 15 1952	25·13

No. 50. Owner unknown. Unused well, dug 10 by 6 feet across and 35 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on top of concrete block northwest corner, even with land surface ; altitude 235·17 feet.

Mar. 13 1951	17·70				
June 3 1951	19·11	Oct. 24 1951	18·74	May 15 1952	22·54

No. 51. Teja Sewji. Irrigation well, dug 11 by 8 feet across and 27 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on lip of sandstone slab, southeast corner, 1·0 foot above land surface ; altitude 223·39 feet.

Mar. 13 1951	14·75				
June 3 1951	15·36	Oct. 23 1951	14·93	May 15 1952	21·23

APPENDIX 12—*contd.*

No. 52. Jiva Natha. Irrigation well, 11 by 6 feet across and 36 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on lip of sandstone slab, southeast corner, 2·0 feet above land surface ; altitude, 233·87 feet.

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
Mar. 14, 1951 .	25·51				
June 2, 1951 .	26·42	Oct. 24, 1951 .	25·39	May 15, 1952 .	31·40

No. 53. Owner unknown. Irrigation well, dug 6 feet square with a 6 inch boring at the bottom, total depth reported 81 feet. Water from Upper Bhuj sandstone. Measuring point, arrow on edge of rubble masonry curb, west side, 2·0 feet above land surface ; altitude 232·69 feet.

Mar. 14, 1951 .	23·42				
June 2, 1951 .	24·29	Oct. 24, 1951 .	23·32	May 15, 1952 .	30·01

No. 54. Bhawan Patel. Irrigation well, dug 10 by 7 feet across and 34 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on masonry rubble curb, west side, 1·0 foot above land surface; altitude 229·80 feet.

Mar. 14, 1951 .	21.74				
June 2, 1951 .	21.12	Oct. 24, 1951 .	20·76	May 15, 1952 .	25·82

No. 55. Lalji Wasta. Irrigation well, dug 8 by 9 feet across and 35 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on lip of sandstone slab, northwest corner, 1·0 foot above land surface ; altitude 229·47 feet.

Mar. 14, 1951 .	19.90				
June 2, 1951 .	20·96	Oct. 24, 1951 .	20·29	May 15, 1952 .	27·40

No. 56. Khora Nepa Mistry. Irrigation well, dug 12 by 6 feet across and 39 feet deep. Water from Upper Bhuj coarse sandstone. Measuring point, arrow on sandstone slab, southwest corner, even with land surface ; altitude 230·91 feet.

Mar. 14, 1951 .	21·09				
June 2, 1951 .	21·86	Oct. 24, 1951 .	21·56	May 16, 1952 .	28·61

APPENDIX 12—*contd.*

No. 57. Owner unknown. Unused well, dug 6 by 8 feet across and 17 feet deep. Water from Deccan trap decomposed and jointed. Measuring point, arrow on lip of sandstone slab, southeast side, even with land surface ; altitude 217·54 feet.

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
Mar. 15, 1951 .	11·60	June 2, 1951 .	12·02	Oct. 27, 1951 .	11·68

No. 58. Owner unknown. Unused well, dug 14 by 10 feet across and 27 feet deep. Measuring point, arrow on sandstone slab, southwest side, at land surface ; altitude 223·33 feet.

Mar. 15, 1951 .	15·76	Oct. 24, 1951 .	15·62	May 15, 1952 .	19·72
June 2, 1951 .	16·21				

No. 59. Jivan Ratna. Irrigation well, dug 10 by 8 feet across and 33 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on sandstone slab, middle of north side, at land surface ; altitude 224·50 feet.

Mar. 15, 1951 .	18·43	Oct. 24, 1951 .	16·61	May 15, 1952 .	21·09
June 2, 1951 .	17·05				

No. 60. Mahanji. Irrigation well, dug 9 by 8 feet across and 36 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on sandstone slab, southeast corner, 2·0 feet above land surface ; altitude 230·57 feet.

Mar. 16, 1951 .	15·85	Oct. 24, 1951 .	15·55	May 15, 1952 .	25·89
June 3, 1951 .	22·44				

No. 61. Narsi Arja. Irrigation well, dug 11 by 8 feet across and 34 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on sandstone slab, northeast corner, 3·0 feet above land surface ; altitude 233·93 feet.

Mar. 16, 1951 .	18·90	Oct. 24, 1951 .	19·00	May 15, 1952 .	26·79 (pumping)
June 3, 1951 .	19·35				

APPENDIX 12—*contd.*

No. 63. Owner unknown. Unused well, dug 5 feet square and 30 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on edge of sandstone slab, east side, even with land surface; altitude 235·18 feet.

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
Mar. 16, 1951 .	22·70	Oct. 24, 1951 .	22·10	May 14, 1952 .	27·00
June 3, 1951 .	22·58				

No. 64. Owner unknown. Irrigation well, dug 12 by 7 feet across and 31 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on lip of sandstone slab, southwest corner, even with land surface; altitude 226·36 feet.

Mar. 16, 1951 .	20·90	Oct. 24, 1951 .	20·48	May 16, 1952 .	25·50
June 2, 1951 .	21·84				

No. 65. Bhimji Raghu Mistry. Irrigation well, dug 14 by 8 feet across and 42 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on lip of sandstone slab, east side, 2·0 feet above land surface; altitude 237·91 feet.

Mar. 16, 1951 .	26·20	Oct. 24, 1951 .	27·03	May 15, 1952 .	32·10
June 2, 1951 .	27·28				

No. 66. Jiva Natha. Irrigation well, dug 17 by 6 feet across and 51 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on sandstone slab, northeast corner, 2·0 feet above land surface; altitude 240·32 feet.

Mar. 16, 1951 .	29·76	Oct. 24, 1951 .	30·48	May 16, 1952 .	35·75
June 2, 1951 .	30·09				

No. 67. Owner unknown. Irrigation well, dug 8 by 6 feet across and 35 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on lip of sandstone slab, south west side, 1·0 foot above land surface; altitude 238·21 feet.

Mar. 17, 1951 .	21·55	Oct. 24, 1951 .	21·54	May 15, 1952	24·74
June 3, 1951 .	21·57				

No. 68. Owner unknown. Unused well, dug 10 by 8 feet across, and 31 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on lip of sandstone slab, centre of east side, 2·0 feet above land surface ; altitude 238·41 feet.

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
Mar. 17, 1951	21·58	Oct. 24, 1951	21·84	May 15, 1952	25·14
June 3, 1951	21·98				

No. 69. Owner unknown. Irrigation well, dug 10 by 8 feet across and 31 feet deep. Water from Deccan trap jointed and decomposed. Measuring point, arrow on sandstone slab, east side, 3·0 feet above land surface ; altitude 218·42 feet.

Mar. 17, 1951	11·31	Oct. 24, 1951	11·71	May 15, 1952	25·60
June 3, 1951	11·98				

No. 71. Dhanji Lalji. Irrigation well, dug 9 feet square and 44 feet deep with a boring of unknown depth at the bottom. Water from Upper Bhuj sandstone. Measuring point, arrow on projected sandstone slab, east side, 1·0 foot above land surface ; altitude 261·01 feet.

Mar. 18, 1951	34·99	Nov. 12, 1951	34·49	May 12, 1952	38·48
June 6, 1951	31·67				

No. 76. Owner unknown. Unused well, dug 7 feet square and 44 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on projected sandstone slab, centre of south side, 1·0 foot above land surface ; altitude 257·09 feet.

Mar. 10, 1951	36·46	Nov. 12, 1951	37·93	May 16, 1952	40·05
June 6, 1951	37·17				

No. 81. Mangalgar Bau. Unused well, dug 10 by 7 feet across and 64 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow at concrete chute below windlass, even with land surface ; altitude 253·47 feet.

Mar 27, 1951	54·00	Nov. 11, 1951	57·78	May 12, 1952	62·34
June 6, 1951	55·63				

No. 90. Shewji Shamji. Unused well, dug 12 by 7 feet across and 40 feet deep. Water from Upper Bhuj sandstone. Measuring point, lip of projecting sandstone slab, south side.

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
Apr. 1, 1951 .	33·90	Apr. 19, 1951 .	34·67	May 8, 1951 .	35·05
Apr. 10, 1951 .	34·27	May 3, 1951 .	35·10	May 15, 1951 .	35·27
Apr. 17, 1951 .	34·49	May 5, 1951 .	35·13		

No. 96. Manaklal. Irrigation well, dug 16 by 14 feet across and 48 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on projecting sandstone slab, southeast corner, 1·0 foot above land surface ; altitude 196·15 feet.

Apr. 23, 1951 .	32·20	Nov. 11, 1951 .	39·50	May 12, 1952	45·85
June 6, 1951 .	38·20				

No. 114. Owner unknown. Unused well, dug 6 feet square and 42 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on projecting sandstone slab, north side, even with land surface; altitude 258·87 feet.

May 3, 1951 .	29·70	Nov. 11, 1951 .	32·29	May 14, 1952 .	34·99
June 7, 1951 .	30·22				

No. 115. Owner unknown. Unused well, dug 28 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on top of curb, southeast corner, even with land surface ; altitude 239·79 feet.

May 6, 1951 .	26·84	June 3, 1951 .	23·13	Oct. 24, 1951 .	23·35

No. 116. Owner unknown. Unused well, dug 9 by 7 feet across and 27 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on projecting sandstone slab, centre of east side, 1·0 foot above land surface ; altitude 237·57 feet.

May 9, 1951 .	23·68	Nov. 11, 1951 .	24·70	May 14, 1952	26·90
June 7, 1951 .	23·94				

APPENDIX 12—*contd.*

No. 119. Bhagat Bali Bauri (Temple). Public well, dug 5 feet in diameter and 84 feet deep. Measuring point, arrow on top of curb, east side, 1·0 foot above land surface ; altitude 256·16 feet.

Date	Dpth to weater (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
May 9, 1951 .	73·82	Nov. 12, 1951 .	74·13	May 14, 1952 .	75·34
June 10, 1951 .	73·60				

No. 120. Owner unknown. Unused well, dug 11 by 6 feet across and 49 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on projecting sandstone slab, west side, 1·0 foot above land surface ; altitude 285·28 feet.

May 10, 1951 .	34·97	Nov. 13, 1951 .	37·77	May 16, 1952 .	40·28
June 5, 1951 .	35·41				

No. 121. Owner unknown. Unused well, dug 9 by 6 feet across and 53 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on projecting sandstone slab, south side, 2·0 feet above land surface ; altitude 277·84 feet.

May 10, 1951 .	27·96	Nov. 13, 1951 .	30·35	May 16, 1952 .	32·81
June 5, 1951 .	28·38				

No. 124. Hirji Dunji. Irrigation well, dug 10 by 17 feet across and 39 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on projecting sandstone slab, south side, 2·0 feet above land surface ; altitude 266·90 feet.

May 11, 1951 .	19·09	Nov. 13, 1951 .	20·52	May 16, 1952 .	23·06
June 5, 1951 .	19·42				

No. 127. Abu Galeria. Irrigation well, dug 10 by 6 feet across and 44 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on top of curb, south side, 3·0 feet above land surface ; altitude 279·89 feet.

May 12, 1951 .	26·90	Nov. 13, 1951 .	29·84	May 16, 1952 .	30·37
June 10, 1951 .	25·90				

APPENDIX 12—*contd.*

No. 128. Pachan Walji. Public well, dug 4 feet in diameter and 64 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on raised platform, north side, 2·5 feet above land surface; altitude 331·42 feet.

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
May 12, 1951 .	55·30	Nov. 13, 1951 .	56·20	May 16, 1952 .	57·65
June 10, 1951 .	55·36				

No. 129. Viram. Irrigation well, dug 9 by 7 feet across with a 6 inch boring at the bottom and 142 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on projecting sandstone slab 3·0 feet above land surface; altitude 320·21 feet.

May 12, 1951 .	40·22	Nov. 13, 1951	80·03	May 16, 1952 .	40·79
June 11, 1951 .	37·00				

No. 130. Govind Khanji. Irrigation well, dug 10 by 8 feet across and 51 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on projecting sandstone slab, east side, 1·0 foot above land surface; altitude 289·75 feet.

May 12, 1951 .	34·13	Nov. 13, 1951 .	34·23	May 13, 1952 .	38·18
June 9, 1951 .	31·33				

No. 158. Owner unknown. Unused well, dug 7 by 5 feet across and 36 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on lip of sandstone slab, east side, 1·0 feet above land surface; altitude 282·85 feet.

June 5, 1951 .	30·90	Nov. 12, 1951 .	31·91	May 14, 1952 .	33·89

No. 159. Owner unknown. Irrigation well, dug 12 by 6 feet across and 41 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on lip of projecting sandstone slab, south side, 3·0 feet above land surface; altitude 239·60 feet.

June 5, 1951 .	36·03	Nov. 11, 1951 .	38·30	May 14, 1952 .	41·38

APPENDIX 12—*contd.*

No. 160. Owner unknown. Irrigation well, dug 10 feet square and 42 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on projecting sandstone slab, east side, 2·0 feet above land surface; altitude 234·48 feet.

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
June 6, 1951	32·68	Nov. 11, 1951	35·27	May 12, 1952	38·43

No. 161. Ratna Nara. Irrigation well, dug 12 by 7 feet across and 54 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on projecting sandstone slab, east side, 1·0 foot above land surface; altitude 246·54 feet.

June 7, 1951	43·91	Nov. 11, 1951	46·94	May 14, 1952	47·24

No. 162. Parbat Vira. Irrigation well, dug 13 by 21 feet across and 55 feet deep with a boring at the bottom whose depth not known. Water from Upper Bhuj sandstone. Measuring point, arrow on projecting sandstone slab, southeast corner, 1·0 foot above land surface; altitude 256·63 feet.

June 7, 1951	32·77	Nov. 11, 1951	30·49	May 14, 1952	35·11

No. 163. Ramji Hardas. Irrigation well, dug 9 by 13 feet across and 53 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on projecting sandstone slab, east side, 1·0 foot above land surface; altitude 279·22 feet.

June 9, 1951	39·23	Nov. 12, 1951	44·04	May 13, 1952	44·04

No. 164. Owner unknown. Unused well, dug 8 by 6 feet across and 43 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on projecting sandstone slab, centre of east side, 1·0 foot above land surface; altitude 285·95 feet.

June 9, 1951	31·49	Nov. 12, 1951	32·68	May 13, 1952	34·77

No. 165. Laddaram Kheta. Unused well, dug 11 by 8 feet across with a boring at the bottom, total depth 200 feet. Water from Upper Bhuj sandstone. Measuring point, arrow on projecting sandstone slab, east side, 1·0 foot above land surface ; altitude 278·31 feet.

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
June 9, 1951 .	32·10	Nov. 12, 1951 .	33·56	May 13, 1952 .	35·35

No. 166. Owner unknown. Unused well, dug 6 feet square and 40 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on projecting sandstone slab, north side, even with land surface ; altitude 293·48 feet.

June 9, 1951 .	34·51	Nov. 13, 1951 .	35·49	May 13, 1952 .	36·60

No. 167. Kanji Premji. Unused well, dug 9 by 6 feet across and 51 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on projecting sandstone slab, east side, 1·0 foot above land surface ; altitude 304·96 feet.

June 9, 1951 .	35·91	Nov. 13, 1951 .	37·13	May 13, 1952 .	37·00

No. 168. Owner unknown. Unused well, dug 8 by 6 feet across and 40 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on projecting sandstone slab, south side, 1·0 foot above land surface ; altitude 272·37 feet.

June 10, 1951 .	22·49	Nov. 13, 1951 .	24·01	May 16, 1952 .	27·17

No. 169. Ransore Gala. Irrigation well, dug 10 by 8 feet across with a boring at the bottom, total depth 89 feet. Water from Upper Bhuj sandstone. Measuring point, arrow on projecting sandstone slab, east side, 2·0 feet above land surface ; altitude 315·73 feet.

June 11, 1951 .	28·96	Nov. 13, 1951 .	32·05	May 16, 1952 .	32·00

No. 170. Owner unknown. Irrigation well, dug 8 by 7 feet across and 38 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on projected sandstone slab, centre of east side, 1·0 foot above land surface ; altitude 327·01 feet.

June 11, 1951 .	28·31	Nov. 13, 1951 .	29·10	May 16, 1952 .	30·63

APPENDIX 12—*contd.*

No. 171. Owner unknown. Unused well, dug 8 by 6 feet across and 34 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on projecting sandstone slab, east side, 0·5 foot above land surface ; altitude 325·96 feet.

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
June 11, 1951	30·31	Nov. 13, 1951	31·35	May 16, 1952	33·79

No. 172. Himmat Singh. Irrigation well, dug 11 by 8 feet across and 38 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on projecting sandstone slab, west side, 2·0 feet above land surface ; altitude 285·28 feet.

June 11, 1951	26·82	Nov. 13, 1951	27·70	May 16, 1952	37·16

No. 173. Karamsingh Govinda. Irrigation well, dug 13 by 7 feet across and 34 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on projecting sandstone slab, east side, 2·0 feet above land surface ; altitude 269·84 feet.

June 11, 1951	22·93	Nov. 13, 1951	23·70	May 16, 1952	26·78

No. 174. Bhojrajji Sheshmalji. Irrigation well, dug 9 by 8 feet across and 29 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on projecting sandstone slab, south side, 1·0 foot above land surface ; altitude 280·55 feet.

June 11, 1951	24·23	Nov. 13, 1951	25·05	May 16,1952	27·56

No. 175. Ratnar Das. Irrigation well, dug 9 by 8 feet across and 29 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on projecting sandstone slab, centre of east side, 2·0 feet above land surface ; altitude 236·34 feet.

June 13, 1951	23·82	Nov. 11, 1951	25·63	May 14, 1952	28·24

No. 176. Apji Shivji. Irrigation well, dug 10 by 9 feet across, and 34 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on sandstone slab, centre of south side, 1·0 foot above land surface ; altitude 268·13 feet.

June 13, 1951.	20·99	Nov. 13, 1951	22·50	May 16, 1952	25·70

No. 177. Sutar Harji Harijan. Irrigation well, dug 17 by 6 feet across with a boring at the bottom, total depth reported 95 feet. Water from Upper Bhuj grey brown sandstone. Measuring point, arrow on projecting sandstone slab, south side, 1·0 foot above land surface ; altitude 272·08 feet.

Date	Depth to water (feet)	Date	Depth to water (feet)	Date	Depth to water (feet)
June 13, 1951 .	26·56	Nov. 13, 1951 .	33·03	May 16, 1952 .	26·17

No. 297. Owner unknown. Unused well, dug 6 feet square and 52 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on sandstone slab, west side, 1·0 foot above land surface ; altitude 273·79 feet.

Nov. 14, 1951 . . .	44·86	May 13, 1952 . . .	46·63

No. 538. Owner unknown. Unused well, dug 10 by 7 feet across and 41 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on middle sandstone slab, east side, 2·0 feet above land surface ; altitude 281·38 feet.

Dec. 25, 1951 . . .	32·66	May 14, 1952 . . .	35·18

No. 553. Owner unknown. Unused well, dug 6·5 feet square and 43 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on top of curb north side, even with land surface ; altitude 289·08 feet.

Dec. 22, 1951 . . .	42·38	May 13, 1952 . . .	43·29

No. 560. Owner unknown. Unused well, dug 7 by 6 feet across and 66 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on projecting sandstone slab, north east side, even with land surface ; altitude 320·78 feet.

Dec. 20, 1951 . . .	63·32	May 13, 1951 . . .	66·92

APPENDIX 12—*concld.*

No. 639. Dayashankar Shyamji. Unused well, dug 8 by 6 feet across and 74 feet deep. Water from Upper Bhuj Coarse white sandstone. Measuring point, arrow on top of middle projecting sandstone slab, east side, 2·0 feet above land surface ; altitude 305·77 feet.

Date	Depth to water (feet)	Date	Depth to water (feet)
Feb. 4, 1952	64·46	May 13, 1952 . . .	66·06

No. 642. Rana Rura. Irrigation well, dug 8 feet square and 69 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on top of middle sandstone slab, north east side, 2·0 feet above land surface ; altitude 297·07 feet.

Feb. 5, 1952	63·35	May 13, 1951	64·16

No. 683. Jaisingh Jetha. Irrigation well, dug 8 by 7 feet across and 78 feet deep. Water from Upper Bhuj Coarse white sandstone. Measuring point, arrow on top of middle projecting sandstone slab, south side, 2·0 feet above land surface ; altitude 308·21 feet.

Feb. 3, 1952	71·58	May 13, 1952	68·68

No. 689. Jiva Allah. Irrigation well, dug 8 by 5 feet across and 78·5 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on top of sandstone slab, centre of east side, even with land surface ; altitude 319·86 feet.

Jan. 15, 1952	73·79	May 13, 1952	72·92

No. 690. Jai Singh Ranmal. Irrigation well, dug 8 by 6 feet across and 68 feet deep. Water from Upper Bhuj sandstone. Measuring point, arrow on top of sandstone slab, centre of east side, 3·0 feet above land surface ; altitude 291·31 feet.

Feb. 14, 1952 . . .	68·20*	May 13, 1952	60·10

*Pumping level.

APPENDIX 13.7

Pumpage from tube wells (A_5, B_1 and B_3) in the Viri area, in thousands of gallons per day, November 1951 to May 1954.

Date.	1951	
	November	December
1	—	51
2	—	149
3	—	123
4	—	162
5	—	157
6	—	165
7	90	180
8	279	173
9	207	176
10	207	160
11	216	184
12	261	206
13	324	175
14	360	150
15	219	233
16	153	213
17	231	180
18	195	187
19	198	203
20	201	173
21	216	225
22	186	157
23	99	180
24	216	292
25	174	300
26	174	240
27	162	277
28	171	240
29	141	205
30	168	225
31	—	225
TOTAL	4,848	5,967

APPENDIX 13—*contd.*

Date	1952											
	January	February	March	April	May	June	July	August	September	October	November	December
1	156	238	284	327	437	338	426	279	291	363	403	406
2	243	205	299	295	246	350	325	249	356	404	395	356
3	156	223	249	327	305	281	328	261	350	407	439	356
4	159	260	318	*504	302	331	319	335	358	341	398	409
5	153	199	344	240	279	292	303	240	344	382	371	338
6	195	284	295	278	311	347	275	273	359	372	341	347
7	153	247	260	344	302	347	290	297	332	427	379	285
8	168	257	241	302	181	350	293	282	323	436	372	285
9	186	265	308	311	334	360	300	294	350	415	369	385
10	201	215	254	247	324	335	284	276	344	439	376	383
11	108	265	289	285	334	347	268	309	329	430	374	383
12	168	305	286	283	356	338	322	323	350	377	374	329
13	159	326	263	329	334	358	287	273	358	377	359	320
14	162	199	302	321	311	360	312	344	341	408	356	291

15	171	249	286	328	308	363	312	294	377	412	371	279
16	147	217	238	331	322	341	300	344	359	386	303	270
17	162	226	257	331	322	350	331	350	368	424	303	291
18	156	241	289	321	316	353	252	344	377	371	383	300
19	174	387	222	334	319	347	265	329	368	386	359	240
20	150	278	308	383	338	282	230	317	359	386	323	252
21	207	266	302	321	303	338	205	362	377	362	335	276
22	183	260	295	273	309	339	224	421	368	362	358	249
23	213	245	305	241	328	312	211	332	353	448	338	249
24	204	238	302	392	366	322	208	341	364	374	341	250
25	216	245	286	349	404	331	237	297	343	430	353	320
26	213	215	259	362	369	331	218	323	359	365	285	294
27	201	269	279	390	319	341	252	317	359	376	282	303
28	219	284	299	340	350	341	223	359	344	401	303	249
29	222	264	164	386	331	328	234	359	392	433	294	276
30	210	..	364	362	331	344	252	356	438	525	312	285
31	234	..	270	..	347	..	252	356	..	335	..	249
TOTAL	5,679	7,372	8,717	9,837	10,038	10,092	8,538	9,836	10,690	12,349	10,509	9,522

APPENDIX 13—*contd.*

Date	1953											
	January	February	March	April	May	June	July	August	September	October	November	December
1	249	288	320	356	320	383	356	401	392	383	371	386
2	258	285	338	401	404	412	338	392	329	362	386	279
3	249	285	335	356	390	415	359	362	472	368	389	392
4	297	297	326	326	351	421	359	386	350	362	374	317
5	267	276	338	309	368	427	371	338	317	398	418	332
6	223	237	323	326	376	424	445	326	285	409	383	320
7	276	285	303	311	370	409	389	300	285	353	353	303
8	249	276	314	374	423	221	398	255	317	374	357	291
9	264	285	306	303	423	418	356	273	356	445	392	359
10	249	276	358	386	426	409	350	314	249	392	392	347
11	223	285	329	320	379	427	338	285	427	380	389	329
12	258	258	320	320	434	430	335	309	403	400	420	320
13	312	285	320	401	407	409	320	332	374	415	406	329
14	285	323	350	365	401	398	335	383	401	401	416	344

15	294	294	306	401	406	406	338	406	385	380	383	320
16	249	356	368	368	395	421	312	332	341	472	386	353
17	240	311	359	401	374	365	380	314	365	427	395	335
18	285	329	347	368	362	353	383	309	332	395	371	320
19	249	309	371	331	359	409	401	297	347	421	401	347
20	267	276	306	331	371	433	401	306	338	418	353	335
21	249	276	306	351	387	392	401	249	374	401	366	314
22	249	303	320	315	432	383	448	300	362	418	362	303
23	335	291	323	387	415	356	454	303	344	377	371	332
24	276	300	332	445	384	374	403	311	353	418	362	315
25	273	300	294	433	381	374	395	309	427	412	392	306
26	249	291	341	436	360	350	361	317	421	383	406	338
27	282	362	324	451	433	386	383	311	368	406	386	309
28	276	338	365	427	406	332	386	350	409	374	368	311
29	273	—	365	445	403	380	439	365	392	415	353	291
30	273	—	356	445	392	377	430	323	421	344	279	294
31	225	—	401	—	398	—	395	285	—	295	—	307
Total	8,194	8,277	10,374	11,189	12,130	11,694	11,750	10,043	10,915	12,307	11,387	10,078

APPENDIX 13—*contd.*

	1954				
Date	January	February	March	April	May
1	294	300	329	412	519
2	347	303	329	420	546
3	311	338	329	412	564
4	297	306	326	418	564
5	306	326	339	418	522
6	320	347	324	407	528
7	309	312	337	459	534
8	306	344	363	446	570
9	317	335	384	446	564
10	300	365	381	446	504
11	344	386	371	465	546
12	297	409	355	439	552
13	341	383	386	444	670
14	347	392	363	436	611
15	297	303	389	540	635
16	309	338	389	481	700
17	320	356	389	475	623
18	329	424	412	510	665
19	314	362	425	519	617
20	338	371	345	558	688
21	338	356	415	531	546
22	356	374	376	510	492
23	371	365	384	540	540
24	297	356	412	519	611
25	332	350	386	546	534

APPENDIX 13—*concld.*

	1954				
Date	January	February	March	April	May
26	323	314	394	531	587
27	365	371	384	546	558
28	303	371	399	528	611
29	323	—	329	519	641
30	329	—	574	531	599
31	314	—	389	—	581
Total	9,994	9,957	11,707	14,452	18,032

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1P	0·15 mile E. of Viri	Juma Ladda .	Dg	23	9×8	BM	Sandstone, argillaceous.
2P	Do. .	Do.	Dg	21	9×7	BM	Do. .
3P	0·2 mile E. of Viri .	Do.	Dg	25	8×7	BM	Trap, jointed .
4P	0·3 mile ESE. of Viri	..	Dg	23	10×6	..	Do. .
5P	Center of Viri .	Temple .	Dg	58	8×31	..	Do. .
6P	N. side of Viri .	Mosque . .	Dg	32	7×4	..	Do. .
7P	0·12 mile NE. of Viri.	Kanji Bhimji .	Dg	31	12×12	BM	Sandstone .
8P	Do.	..	Dg	28	7×7	..	Trap . .
9P	0·18 mile NNE. of Viri.	..	Dg,B	78	7×8 & 6"	BM	Sandstone . .
10P	1·0 mile SW. of Anjar.	Deva Jetha .	Dg,B	110	..	BM	Do. .
11P	Do. .	Babu Deva Singh	Dg,B	88	..	BM	Sandstone, clayey, white.
12P	0·75 mile SW. of Anjar.	Anjar Sutar .	Dg,B	38	..	BM	Sandstone, clayey, yellowish.
13P	1·0 mile SW. of Anjar.	Walji Sutar .	Dg	45	..	BM	Sandstone, coarse, clayey.
14P	1·0 mile SW. of Anjar.	Walji Sutar and Ramji Vira.	Dg	51	13×7	BM	Sandstone, coarse, clayey.

See footnotes at end of table.

DIX 14.

Khedoi region, Anjar *taluk*, eastern Kutch.

Geologic horizon	Water Level				Use 8	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj.	Edge of curb. center of W. side.		11·81	Mar. 30	I	83	Water has good taste. Well starts in trap ends in sandstone.
Do.	Do.		11·28	Do.	I	82	Do.
Deccan	Lip of proj. SS. slab, N. side.	1·0	11·13	Do.	I	88	Water has good taste.
Do.	Lip of SS. slab, center, E. side.		11·25	Do.	Un		Water has slightly brackish taste.
Do.	Top of curb. S. side.		28·54	Do.	D		Water has brackish taste.
Do.	Top of wall, W. side	1·5	27·30	Do.	D		Curbed 0-10 ft. Water has good taste.
Upper Bhuj.	Lip of SS. slab, N. side.		21·15	Do.	I	86	Irrigates 7 acres by one to 4 motes, working about 8 hrs./day for about 10 months/year. Water has good taste.
Deccan	Top of platform		21·92	Do	D		Curbed 0-21 ft. Water has good taste.
Upper Bhuj.	Lip of SS. slab, center of N. side.	0	25·41	Do.	I	87	Irrigates 2 acres by one to 2 motes. Curbed 0-15 ft. Dug 30 ft., then one boring 48 ft. deep.
Do.	Top of concrete platform.		27·72	Mar. 31	I	86	Dug 45 ft., the one boring 65 ft. deep. Water has good taste.
Do.	Top of wall, S. side.		31·27	Do.	I	84	Dug 43 ft., then one boring 45 ft. deep. Irrigates 2 acres by one to 2 motes.
Do.	Lip of SS. slab, N. side.		29·01	Do.	I	85	Dug 58 ft., then one boring 30 ft. deep in bottom. Encountered trap 0-20 ft. then sandstone 30-88 ft., Irrigates 4 acres by one to 2 motes, working about 8 hrs./day for 10 months/year. Water has good taste.
Do.	Lip of SS. slab, E. side.		26·85	Do.	I	85	Irrigates 2 acres. Water has good taste.
Do.	Lip of SS. slab, N. side.		22·63	Do.	I		Irrigates 4 acres by one to 2 motes. Water has very slightly brackish taste.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type [1]	Depth (feet)	Dimensions (feet)	Method of lift [2]	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
15P	1·0 mile SW. of Anjar.	Raja Ohara .	Dg,B	9	9×7	BM	Sandstone, coarse clayey.
16P	Do.	Mistri Jiva Natha.	Dg,B	+41	18×9 & 6"	BM	Sandstone, white, argillaceous.
17P	Do.	Ratna Hira Patel.	Dg	48	11×7	BM	Do. .
18P	0·75 mile SW. of Anjar.	..	Dg	28	..	..	Sandstone . .
19P	Do.	Hirji Meghji .	Dg	47	11×7	BM	Trap . .
20P	..	..	..	..	..	..	..
21P	0·32 mile SW. of Viri.	..	Dg	30	..	..	Sandstone . .
22P	0·45 mile SW. of Viri.	Kasu Karu .	Dg	17	7×7	BM	Trap, jointed .
23P	Do.	Mamu Hussein .	Dg	24	12×7	BM	Do. .
24P	0·4 mile S. of Viri	Abhu Dinmohamud.	Dg	26	7×7	BM	Do. .
25P	0·6 mile SSE. of Viri.	Seva Mallah .	Dg,B	145	9×5 & 6"	HO	Sandstone, white, argillaceous.

See footnotes at end of table.

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level						
	Measuring Point		Depth to water (feet)	Date of measurement (1951)	Use 3	Temperature (F°)	REMARKS
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj.	Lip of SS. slab, center of S. side.		20·0 0	Mar 31	I	86	Irrigates 3 acres by one to 2 motes. Dug 47 ft. then 2 borings in bottom one 50 ft. deep and one 40 ft. deep. Water has good taste.
Do.	Lip of proj. SS. slab, NE. side.		16·86	Do.	I	82	Irrigates 2 acres by 2 to 4 motes working about 8 hrs./day for 10 months/year. Dug 41 ft., then one boring of unknown depth. Water has brackish taste.
Do.	Top of curb, E. side.		18·03	Do.	I	84	Irrigates 5 acres by one to 2 motes working about 8 hrs./day for 10 months/ year. Water has brackish taste.
Do.	Lip of proj. SS. slab, S. side.		15·28	Do.	Un		
Deccan .	Lip of SS. slab, E. side.		14·82	Do.	I		Irrigates 1-2 acres by one mote. Water has slightly brackish taste.
Upper Bhuj.	Lip of SS. slab, center, N. side.		15·88	Apr. 6	Un		Curbed 0-16 ft.
Deccan .	Lip of SS. slab, center of E. side.	1·0	11·87	Apr. 8	I		Water has good taste. Curbed 0-2ft.
Do.	Top of SS. slab, center, S. side.	0	10·67	Do.	I	83	Water has good taste.
Do.	Top of curb, S. side.	6·0	14·90	Do.	I		Water has brackish taste.
Upper Bhuj.	Lip of SS. slab, center, E. side.	1·0	22·15	Apr. 9	I	88	Irrigates about 3 acres pumping about 8 hrs./day for 10 months/year. Dug 45 ft., then 2 boring each 100 ft. deep in bottom. Curbed 0-11 ft. Water has slightly brackish taste.

APPEN

Hydrologic date for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
26P	0·5 mile S. of Viri .	..	Dg	23	..	BM	Sandstone, coarse.
27P	0·25 mile E. of Viri	Nanji Bhimji .	Dg	29	12×8	..	Trap, jointed .
28P	0·37 mile N. of Viri	Hira Rura .	Dg	24	9×9	..	Do. . .
29P	0·4 mile N. of Viri .	..	Dg	28	12×7	..	Trap, jointed .
30P	1·5 miles NW. of Devalia.	..	Dg	23	6	..	Do. .
31P	0·37 mile NNE. of Viri.	Osman Jusab .	Dg	22	7×7	BM	Trap, jointed, weathered.
32P	0·25 mile E. of Viri.	Seva Mala .	Dg	26	13×9	BM	Do. .
33P	..	..	..	..	..	..	..
34P	1·5 miles SSE. of Anjar.	Deca Sorthia	Dg	33	8×6	..	Trap, jointed, weathered.
35P	NW. side of Meghpur.	Patel . .	Dg	15	9	..	Trap (?) . .
36P	0·5 mile ENE. of Meghpur (Khumbaria).	..	Dg	27	9	..	Sandstone . .
37P	0·12 mile E. of Anjar.	Noor Mohammad Khatri.	Dg	64	12×12	BM	Trap, massive, weathered.

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk;* eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj.	Lip of SS. slab, center of S. side.	2·0	14·90	Apr. 9	I		Water has slightly brackish taste. Curbed 0-7 ft.
Deccan .	Lip of SS. slab, center of E. side.	2·0	10·78	Apr. 11	I		Water has brackish taste. Curbed 0-9 ft.
Do.	Lip of SS. slab, E. side.	2·0	17·22	Do.	I	81	Water has good taste. Curbed 0-16 ft.
Do.	Lip of SS. slab, E. side.	2·0	17·72	Do.	I		Water has good taste. Curbed 0-8 ft.
Do.	Top of curb, S. side.		15·31	Apr. 12	S		Water has brackish taste. Curbed 0-11 ft.
Do.	Lip of SS. slab, N. side.	0·5	17·41	Apr. 14	I,D	83	Water has good taste. Curbed 0-4 ft.
Do.	Lip of SS. slab, W. side.	0	11·46	Do.	I,D	83	Water has brackish taste. Curbed 0-7 ft.
..	..	..	..	..	..	..	
Do.	Lip of SS. slab, E. side.	0	13·14	Apr. 27	I		Water has brackish taste. Curbed 0-14 ft.
Do.	Top of SS. slab, E. side.	3·0	12·00	Do.	S	80	Water has brackish taste. Curbed 0-12 ft.
Manchhar	Top of SS. curb, S. side.	1·0	21·54	Do.	I		Water odiferous but taste good. Curbed 0-22 ft.
Deccan .	Top of curb, N. side.	0	18·24	Do.	I		Irrigates one acre part of year. Water has brackish taste. Curbed 0-7 ft.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
S1	1·0 mile WNW. of Anjar.	Govind Vegar Mistry.	Dg	47	21×13	BM	Sandstone, white, argillaceous.
S2	0·75 miles NNW. of Anjar.	Lalji Kachra .	Dg	38	10×7	BM	Trap, jointed
S3	1·0 mile NNW. of Anjar.	..	Dg	54	14×11	BM	Trap, jointed, and sandstone(?).
S4	Do.	Kella Karamsi .	Dg,B	113	10×10 & 6"	BM	Sandstone . .
S5	1·12 miles NNW. of Anjar.	Shah Ginning Factory.	Dg,B	78	12 & 6"	HC	Sandstone, soft .
S6	Do.	Jeda Mnda & Nayaratna Mistry.	Dg	23	9	BM	Do. .
S7	1·0 mile NW. of Anjar.	..	Dg	47	17×10	..	Do. .
S8	Do.	Ajit Singh Bhai	Dg	63	15×9	HC	Do. .
S9	1·12 miles NW. of Anjar.	Holy well .	Dg	37	10×8	..	Sandstone . .
S10	Do.	..	Dg	41	17×7	HC	Do. .

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj.	Lip of SS. slab, E. side.		34·06	Mar. 30	I		Irrigates about 9 acres with 2 to 4 motes. Water has slightly brackish taste. Curbed 0-20 ft.
Deccan .	Lip of SS. slab, SE. side		31·22	Do.	I		Very meager yield. Water has brackish taste. Curbed 0-5 ft.
Deccan and Upper Bhuj (?).	Do.	10·0	37·22	Do.	I		Water has a slightly brackish taste.
Upper Bhuj.	Lip of SS. slab, E. side.	0	39·50	Do.	I		Irrigates 1¼ acres by 1 to 2 motes. Water has slightly brackish taste. Curbed 0-10 ft. Trap encountered 0-12 ft. and sandstones below. Dug 53 ft., then one boring 60 ft. deep.
Do.	Edge of wooden sill.	0	17·60	Do.			Industrial use in ginning factory. Dug 28 ft., then one boring 50 ft. deep. Pumped 10 hrs./day through out year. Water has good taste. Curbed 0-28 ft.
Do.	Lip of proj. SS. slab, W. side.	0	22·88	Do.	I		Irrigates 2½ acres by 1 to 2 motes working 8 hrs./day through out year. Water has good taste. Curbed 0-33 ft.
Do.	Lip of proj. SS. slab, E. side.		31·42	Mar. 31	Un		Water has a fair taste. Curbed 0-15 ft.
Do.	Do.	0	49·17 (pumping)	Do.	I		Yields 160 gal./min. to irrigate about 6 acres. Two borings of 50 and 60 ft. now considered plugged.
Do.	Do.		29·42	Do.	Un		Well reputed to be devoted to the Almighty, hence water not used. Curbed 0-8 ft. Water has good taste.
Do.	Lip of proj. SS. slab, S. side.		37·50 (pumping)	Do.	I		Yields 130 gal./min. with a drawdown of 4 to 5 ft. and is pumped about 8 hrs./day through out most of year. Irrigates 4 acres. Water has good taste.

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
S11	1·12 miles NW. of Anjar.	..	Dg	41	16	BM	Sandstone, coarse, argillaceous.
S12	1·12 miles NNW. of Anjar.	Nanji Gokul Mistry	Dg	49	11×8	BM	Sandstone, grayish yellow.
S13	1·5 miles N. of Anjar.	..	Dg	26	4	..	Clay, mottled red.
S14	1·37 miles N. by W. of Anjar.	..	Dg	46	12×8	BM	Sandstone, white, soft.
S15	1·38 miles NNW. of Anjar.	Velji Seth .	Dg,B	46+	10 & 6"	BM	Sandstone, white, soft.
S16	Do.	Lalji Kachra	Dg	48	10×7	BM	Do.
S17	1·25 miles NNW of Anjar.	Deosi Mora .	Dg	54	11×11	BM	Trap, weathered .
S18	1·25 miles N. of Anjar.	Harilal Kanji .	Dg	57	14	BM	Sandstone (?)
S19	1·25 miles NNW. of Anjar.	Lalji Kachra .	Dg	40	8	BM	Do.
S20	Do.	Jiwaram Madan	Dg	39	10×11	BM	Sandstone, white, soft.
S21	Do.	Lalji Kachra .	Dg	41	9 to 6	BM	Do.
S22	Do.	Kheta Nathu .	Dg,B	101	13×10	BM	Sandstone, yellowish brown.

See footnotes: end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj.	Lip of proj. SS. slab, W. side.	2·0	35·80	Mar. 31	I		Curbed 0-10 ft. Water has good taste.
Do.	Lip of proj. SS. slab, NW. side.		33·16	Do.	I		Encountered trap 0-7 ft. and sandstone below. Curbed 0-7 ft. Water has good taste.
Manchhar	Edge of curb, N. side.	0	16·31	Apr. 2	P		Curbed 0-16 ft. + Water has a fair taste.
Upper Bhuj.	Lip of SS. slab, E. side.	0	30·06	Do.	I		Irrigates 2½ acres by one to 2 motes working about 10 hrs./day for about 10 months/year. Water has slightly brackish taste. Curbed 0-30 ft.+
Do.	Lip of SS. slab, E. side.		35·35	Do.	I		Dug 40 ft. then 2 borings of unknown depth. Water has good taste. Curbed 0-35 ft.+
Do.	Do.		36·22	Do.	I		Water has good taste.
Deccan .	Do.		40·40	Do.	I		Irrigates about 2 acres by one to 2 motes. Meager quantity. Water has slightly brackish taste. Curbed 0-15 ft.
Upper Bhuj(?).	Do.	0	32·44	Apr. 9	I		Irrigates about 2½ acres by one to 2 motes working about [illegible] hrs./day through out year. Water has a good taste. Curbed 0-33 ft.+
Do.	Do.	2·0	28·46	Do.	I		Irrigates about 2 acres by one to 2 motes working 8 hrs./day throughout year. Water has good taste. Curbed 0-29 ft.+
Upper Bhuj.	Edge of curb, N. side.	2·0	31·93	Do.	I		Irrigates about 2 acres by one to 2 motes working about 8 hrs./day through out year. Water has good taste. Curbed 0-32 ft.+
Do.	Lip of proj. SS. slab, W. side.	2·0	32·18	Do.	I		Irrigates 1½ acres by one to 2 motes. Curbed 0-32 ft.+ Water has good taste.
Do.	Lip of proj. SS. slab, E. side.	0	29·80	Do.	I		Irrigates 1½ acres by one to 2 motes working about 8 hrs./day throughout year. Water has good taste. Curbed 0-15 ft. Dug 41 ft. then one boring 60 ft. deep. 2 other borings plugged.

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
S23	1·25 miles N N W. of Anjar.	Murji Mistry .	Dg	46	9×10	BM	Sandstone Yellowish brown.
S24	Do.	Nanji Kanji .	Dg	35	9×8	BM	Sandstone . .
S25	Do.	Jiva Manji .	Dg	38	8×11	BM	Do.
S26	Do.	Ladhu Khimji .	Dg,B	98	10×8 & 6"	BM	Do.
S27	0·75 mile N. of Anjar.	..	Dg	15	14×8	..	Trap . . .
S28	1·0 mile N. of Anjar	Lachminarayan temple.	Dg	31	8	..	Sandstone, Coarse.
S29	1·25 miles NNW. of Anjar.	Madhavji Hirji.	Dg	40	9	BM	Sandstone . .
S30	1·25 miles WNW. of Anjar.	Manji Nanji .	Dg,B	122	11×8 & 6"	BM	Sandstone, argillaceous, white.
S31	1·25 miles NNW. of Anjar.	Narayan Pragji	Dg,B	45+	10×8	BM	Sandstone . .
S32	0·75 mile NW. of Anjar.	..	Dg	43	11×10	..	Sandstone, grey, ferruginous.
S33	0·6 mile NW. of Anjar.	..	Dg	26	8×10	..	Trap, disintegrated.
S34	0·75 mile WNW. of Anjar.	..	Dg	68	11	..	Sandstone . .
S35	0·75 mile W. of Anjar.	..	Dg	38	11	..	Trap . .

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj.	Lip of proj. SS. slab, W. side.	1·0	33·99	Apr. 9	I		Irrigates 1¼ acres by one to 2 motes. Water has a good taste. Curbed 0-15 ft.
Do.	Lip of proj. SS. slab, SE. side.	1·0	23·02	Do.	I		Irrigates 1¾ acres by one to 2 motes working 8 hrs./day throughout year. Water has good taste. Curbed 0-23 ft.
Do.	Lip of proj. SS. slab, E. side.	0	24·76	Do.	I		Irrigates 2¼ acres by one to 2 motes working about 8 hrs./day throughout year. Water has good taste. Curbed 0-15 ft.
Do.	Lip of proj. SS. slab, NE. side.	2·0	30·28	Do.	I		Irrigates 4½ acres by one to 2 motes. Dug 48 ft. then one boring 50 ft. deep. Curbed 0-31 ft. + Water has good taste.
Deccan	Lip of proj. SS. slab, SE. side.	0	12·78	Apr. 11	Un		Curbed 0-7 ft. Water has very brackish taste.
Upper Bhuj.	Lip of SS. slab, E. side..	0	24·55	Do.	I		Irrigates about 1¼ acres by one mote. Water has good taste.
Do. .	Lip of SS. slab, N. side.	4·0	27·57	Do.	I		Irrigates 1¾ acres by one to 2 motes. Curbed 0-28 ft. + Water has good taste.
Do.	Edge of Curb, W. side.	0	30·90	Do.	I		Irrigates 1½ acres by one to 2 motes. Water has good taste. Curbed 0 31 ft. Dug 42 ft. then one boring 80 ft. deep.
Do.	Edge of curb, E. side.	0	31·73	Do.	I		Irrigates 2 acres by one to 2 motes. Curbed 0-32 ft. Water has good taste. Dug 45 ft., then one boring of unknown depth.
Do.	Lip of SS. slab, E. side.	2·0	34·48	Apr. 22	Un		Water has good taste. Curbed 0-15 ft.
Deccan .	Lip of SS. slab, N. side.	0	13·36	Do.	D		Water has good taste. Curbed 0-10 ft.
Upper Bhuj.	Edge of wood railing. E. side.	2·0	52·89	Do.	Un		Curbed 0-20 ft. Water has good taste.
Deccan .	Do. .	2·5	28·19	Apr. 24	Un		Curbed 0-15 ft. Water has good taste.

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
S36	0·75 mile W. of Anjar.	Golamji Gokul .	Dg	67+	18×7	HC	Sandstone, argillaceous, yellowish brown.
S37	0·75 mile WNW. of Anjar.	Mistry Nathu Dosa.	Dg,B	154	17×7 & 6″	HC	Sandstone . .
S38	1·0 mile WNW. of Anjar.	Do. .	Dg,B	150	10×7 & 6″	HC	Do.
S39	1·12 miles WNW. of Anjar.	Jiva Natha .	Dg	75	20×11	HC	Sandstone, argillaceous.
S40	1·12 miles NW. of Anjar.	..	Dg	67	22×10	HC	Do.
S41	1·25 miles NW. of Anjar.	..	Dg	54	12×7	BM	Do.
S42	0·3 mile N of Anjar	Odhavji Meghji	Dg	54	13	BM	Sandstone, soft .
S43	Do. .	Mosque near cemetery.	Dg,Dr	103	6×5	..	Trap and sandstone

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	Remarks
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj.	Lip of SS. slab, W. side.	0	47·24	April 24	I		Irrigates 6 acres. Dug 67 ft. then one boring of unknown depth. Water has good taste. Curbed 0-5 ft.
Do.	Do.	0	63·18 (pumping)	Do.	I		Irrigates 6 acres pumping 180 gal./min. for about 8 hrs./day through year. Drawdown about 15 ft. after 1¼ hrs. pumping. Dug 74 ft. then 6 borings 70-80 ft. deep. Curbed. 0-10 ft. Water has good taste.
Do.	Lip of proj. SS. slab, E. side.	0	54·69	Do.	I		Irrigates 6 acres pumping 200 gal/min. for about 8 hrs. day through year. Drawdown about 21ft. after 2 hrs. pumping Dug 70 ft. then 2 borings of 60 and 80 ft. Curbed 0-5 ft. Water has good taste.
Do.	Lip of proj. SS. slab, S. side.	0	63·85	Do.	I		Irrigates about 4½ acres pumping 110 gal./min. for 6-7 hrs./day through year. Drawdown about 20 ft. after pumping 3 hrs. Water has good taste. Curbed 0-10 ft. Has 8 borings, now plugged.
Do.	Do.	0	61·80	Do.	I		Irrigates about 3 acres. Water has good taste. Curbed 0-10 ft.
Do.	Do.	1·0	35·98	Apr. 26	I		Water has good taste. Curbed 0-15 ft.
Do.	Do.	1·0	36·11	Do.	I		Irrigates 3 acres by one mote working 8 hrs./day. Water has slightly brackish taste. Curbed 0-87 ft.†
Deccan and Upper Bhuj.	Edge of SS. Curb, S. side.	3·0	23·77	Do.	D		Curbed 0-10 ft. Water has very slightly brackish taste. Dug 44 ft. then drilled 59 ft.

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
844	0·25 mile N. of Anjar.	Ramji Kava .	Dg,B	47+	13	BM	Sandstone, soft, argillaceous.
845	0·15 mile N. of Anjar.	Temple . .	Dg	28	7	..	Sandstone, argillaceous.
846	0·12 mile N. of Anjar.	Meghji Virji .	Dg,B	30+	12	BM	Sandstone, soft, white.
847	0·15 mile NNE of Anjar.	Kutch State Rly.	Dg	30	14	T	Do.
848	0·15 mile NE of Anjar.	Lalji Kachra .	Dg	36	18×18	BM	Sandstone soft, white, argillaceous.
849	0·12 mile NE of Anjar.	Thakorsi Ranchhordas Bhatia.	Dg	42	16×10	BM	Trap . .
850	0·25 mile NE of Anjar.	Do .	Dg	48	9×7	..	Trap and sandstone.
851	0·3 mile E of Anjar.	Jangleswar (Mahadev) Temple.	Dg	39	6×6	..	Trap, weathered .
852	0·25 mile NE of Anjar.	Temple . .	Dg	36	4	..	Do.
853	2·1 miles NNW of Anjar.		Dg	61	11×7	..	Sandstone soft, silty.

See footnotes at end of table.

Khedoi region, Anjar *taluk*; eastern Kutch—*contd.*

Geologic horizon	Water Level				Use S	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj	Lip of proj. SS. slab, N. side.	1·0	29·99	Apr. 26	I	..	Irrigates 1½ acres by one mote working 8 hrs. day. Dug 47 ft. then 2 borings of unknown depth. Water has good taste. Curbed 0-30 ft.+
Do.	Edge of SS. curb, E. side.	3·0	19·94	Do.	D		Water has good taste. Curbed 0-20 ft.+
Do.	Do.	0	22·99	Do.	I		Irrigates about 4 acres by one to 2 motes. Dug 30 ft. then one boring of unknown depth Water has a good taste. Curbed 0-22 ft.+
Do.	Edge of curb	1·5	16·37	Do.	P		Yields about 85 gal./min. with drawdown about 2 ft. after pumping one hour. Curbed 0-17 ft. Water has slightly brackish taste.
Do.	Lip of proj. SS. slab, N. side.	2·5	15·27	Do.	I		Water has good taste. Curbed 0-16 ft.+
Deccan	Do.	0	11·67	Apr. 27	I, S		Curbed 0-12 ft.+ Water has good taste.
Deccan and Bhuj (?)	Lip of SS. slab, S. side.	1·0	13·79	Do.	Un		Curbed 0-9 ft. Water has brackish taste.
Deccan	Top of SS. slab N. side.	2·0	22·31	Apr. 29	P		Water has a very brackish taste.
Do.	Edge of curb	2·0	15·13	Do.	P		Water has bitter salty taste. Curbed 0-15 ft.+
Upper Bhuj	Lip of a slab, N. side.	0	56·88	Do.	S		Curbed 0-57 ft.+

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	0·12 mile E. of Nagalpur.	..	Dg	46	16×9	BM	Sandstone, light-grey.
2	Do.	..	Dg	50	8×6	BM	Do.
3	0·1 mile SSE of Viri.	..	Dg	24	8×18	..	Sandstone
4	0·5 mile N. of Khedoi Mota.	Dioji	Dg	41	8×5	..	Sandstone, brownish white, current bedded.
5	0·25 mile W. of Nagalpur.	Khemji Dosani	Dg	52	9×12	..	Sandstone, yellowish brown.
6	1·25 miles W. of Anjar.	..	Dg	59	14×10	..	Sandstone, light gray.
7	1·37 miles NW of Anjar.	Toll House	Dg	47	7×5	..	Sandstone, med to coarse-grained.
8	3·5 miles NW of Anjar.	..	Dg	60	..	..	Do.
9	At Samparda .	..	Dg	75	..	..	Sandstone, silty yellowish brown.
10	0·62 mile SW of Samparda.	Rana Momaya .	Dg	76	5×10	BM	Sandstone
11	0·25 mile NE of Bhadroi.	..	Dg	74	..	..	Do.
12	0·5 mile W. of Anjar.	..	Dg	41	12	..	Trap, fractured and jointed, hard.
13	Do.	Ranchhor Dass Meghgi.	Dg	63	11×14	BM	Sandstone
14	1·5 miles W. of Anjar.	Mistry Morarji Dosa.	Dg	55	12×13	HC	Sandstone, grey friable.
15	0·25 mile N. of Nagalpur	Premgi son of Ramgi.	Dg,B	228	10×8 and 6"	HC	Sandstone, white friable.
16	0·25 mile SSW of Nagalpur.	..	Dg	56	17×10	BM	Sandstone, yellowish brown, current bedded.
17	0·5 mile W. of Nagalpur.	Shina shrine	Dg	31	5	..	
18	0·5 mile N. of Sidungra.	Daln Dhanji	Dg	53	12×7	BM	Sandstone, yellowish brown, current bedded.

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj	Lip of SS. slab, N. side.	2·0	25·40	Feb. 23	Un	..	Irrigation use part of year. Curbed SS. blocks 0-5 ft.
Do.	Lip of SS. slab, E. side.	0	28·00	Do.	Un	..	Irrigation use part of year. Curbed SS. blocks 0-5 ft.
Do.	Lip of SS. slab, E. side.	0·5	9·52	Do.	Un	..	Curbed SS. blocks 0-5 ft. Well begins at base of Deccan trap.
Do.	Lip of SS. slab, S. side.	0	21·00	Feb. 24	Un	..	Curbed SS. blocks 0-5 ft.
Do.	Lip of SS. slab, E. side.	2·0	26·37	Do.	Un	..	Irrigation use part of year. Curbed SS. blocks 0-15 ft.
Do.	Lip of SS. slab, E. side.	0	35·70	Do.	Un	..	Curbed S.S blocks 0-15 ft.
Do.	Edge of curb, S. side.	0	41·64	Feb. 25	P	..	Step well. No curbing.
Do.	Top of curb .	0	Dry	Do.	Un	..	..
Lower Bhuj	Top of curb, N. side.	0	70·70	Do.	P	..	Step well. Curbed SS. blocks 0-15 ft.
Upper Bhuj	Lip of SS. slab, N. side.	2·0	69·35	Do.	I	84	Worked 8 hrs./day for 11 months/year by one mote, Curbed SS. blocks 0-5 ft.
Do.	Lip of SS. slab, E. side.	2·0	64·15	Do.	Un	..	Irrigation use part of year.
Deccan	Top of curb, SE. side.	2·3	29·26	Feb. 27	Un	..	
Upper Bhuj	Lip of SS. slab, S. side.	0	44·35	Do.	I	84	Irrigates 3 acres by 2 motes. Curbed SS. blocks 0-20 ft. Water has a good taste.
Do.	Lip of SS. slab, E. side.	0	46·40	Do.	I	83	Yields 117 gal./min. Curbed SS. blocks 0-10 ft. Water has a good taste.
Do.	Top of curb, N. side.	1·0	42·32	Do.	I	84	Pumped at 120 gal./min. for 8 hrs./day throughout year. Dug 58 ft. then open bore 170 ft. deep. Curbed SS. Blocks 0-20 ft. Water has good taste.
Do.	Lip of SS. slab, NW corner.	0	34·42	Do.	I	83	Curbed SS. blocks 0-20 ft. Water has good taste.
Do.	Top of curb, N. side.	0	18·06	Do.	D	..	Step well.
Do.	Lip of SS. slab, E. side.	2·0	39·80	Do.	I	..	Yields sufficient water for 2 motes. Curbed SS. blocks 0-20 ft.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
19	0·02 mile SW of Viri.	Kuarji Maoji	Dg	34	10×8	BM	Sandstone
20	0·36 mile W of Viri.	Khema Anda	Dg	44	7×10	BM	Sandstone, pale grey.
21	0·75 mile NE of Khedoi Mota.	Khatay Ragbavji.	Dg,B	69	16×10 and 4″	HC	Sandstone, yellowish brown and white.
22	W. outskirts of Khedoi Nana	..	Dg	38	12×8	BM	Sandstone, light-grey.
23	1·36 miles SW of Khamra.	Ruined temple	Dg	41	7×7	..	Sandstone, coarse, grey to yellowish brown.
24	0·5 mile S. of Khamra.	Babu Yadaugi	Dg	44	9×7	BM	Do.
25	E. edge of Khamra	Amar Singh	Dg,B	186	9×12 and 8″.	HC	Sandstone, yellowish grey.
26	0·75 mile NW of Sidungra.	Temple	Dg	37	6×6	..	Sandstone, coarse, yellowish grey.
27	0·8 mile NW of Anjar.	Nanji Khenga	Dg	42	22×15	BM	Trap, bedded, massive.
28	1·25 miles NNW of Anjar.	..	Dg	41	11×12	BM	Sandstone, greyish.
29	0·25 mile S. of Anjar.	Bhareswar temple	Dg, Dr.	134	.	..	Sandstone
30	At market in Gandhidham.	Sindhu Resettlement Corporation (Open well No. 1).	Dg, Dr.	111	15 and 6″.	HC	Sandstone (?)

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj	Lip of SS. slab, E. side.	0	17·50	Feb. 28	I	83	Yields sufficient water for 2 motes. Curbed S S. blocks 0-18 ft.
Do.	Top of curb, NW. side.	0	29·10	Do.	I	85	Yields water sufficient for 2 motes.
Do.	Lip of SS. slab, SE side.	2·0	28·11	Mar. 1	I	..	Irrigates 10 acres. Pumped at 250 gal./min. for 8 hrs./day and 20 days/month throughout year. Curbed SS. blocks 0-15 ft. Water has a good taste. Dug 47 ft. then 2 bores of 14 ft. and 22 ft.
Do.	Lip of SS. chute, W. side.	0	19·40	Do.	I	84	Yields water sufficient for 2 motes. Curbed SS. blocks 0-15 ft.
Do.	Top of SS. curb, N. side.	0	29·80	Do.	Un	..	Curbed SS. blocks 0-5 ft. Step well.
Do.	Lip of SS. slab, E. side.	0	31·35	Do.	I	..	Yields water sufficient for one mote. Curbed SS. blocks 0-15 ft.
Do.	Top of SS. curb, E. side.	0	45·05	Do.	I	84	Irrigates 4 acres. Pumped at 200 gal./min. for 7 hrs./day through 10 months/year. Dug 55 ft. then open bore of 135 ft. Curbed SS. blocks 0-10 ft.
Do.	Top of SS. curb, S. side.	0	29·85	Do.	Un	..	Curbed S.S. blocks 0-18 ft. Step well.
Deccan	Lip of SS. slab, E. side.	0	21·75	Mar. 31	I	80	Yields water sufficient for 2 motes throughout year. Curbed SS. blocks 0-18 ft. Water has slightly brackish taste.
Upper Bhuj	Lip of SS. slab, W. side.	2·0	31·78	Apr. 9	I	85	Yields water sufficient for 2 motes. Curbed SS. blocks 0-8 ft. Water has good taste.
Do.	Top of curb, S. side.	2·0	Flows at 2 ft. above surface.	Mar. 1	P	..	Well flows at 1 gal./min. during postmonsoon period. Starts in Deccan trap and taps confined water in Bhuj sandstones. Dug 80 ft. then drilled 104 ft.
Manchhar	Top of concrete curb, N. side.	3·0	63·70	Mar. 3	P	..	Pumped about 10 hrs./day. Curbed concrete blocks 0-66 ft. Dug 66 ft. then 3 six-inch drilled holes 30, 35 and 45 feet deep in bottom. Water has brackish taste.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
31	At agricultural station Gandhidham.	Sindhu Resettlement Corporation.	Dr.	116	6"	T	Sandstone (?)
32	At factory in Gandhidham	Sindhu Resettlement Corporation Factory well No. 1	Dr.	110	6"	L	Do.
33	At factory in Gandhidham	Sindhu Resettlement Corporation	Dr.	..	12"	T	Do.
34	At factory in Gandhidham	Sindhu Resettlement Corporation	Dr.	52	6"	..	Do.
35	1·0 mile NW of Gandhidham.	..	Dg	29	5	..	Do.
36	1·0 mile S. of Ratnal	..	Dg	97	10	..	Sandstone, ferruginous, current-bedded.
37	1·25 miles NNW of Nigal.	Ragha Vasta	Dg	63	10×5	BM	Sandstone
38	0·75 mile SSE of Nigal.	Lakhu Hira	Dg	40	7×8	BM	Sandstone, ferruginous.
39	1·8 miles NNE of Pantia.	..	Dg	35	5×5	..	Sandstone, silty
40	0·5 mile SW of Viri	..	Dg	18	7	..	Sandstone
41	0·5 mile SSW of Viri.	..	Dg	33	9×7	..	Sandstone, coarse
42	0·75 mile SW of Viri.	..	Dg	26	10×18	..	Sandstone, white, current-bedded.
43	0·25 mile WNW of Antarjal.	..	Dg	40	6×6	..	Sandstone, conglomeratic.
44	1·75 miles ESE of Shinaya.	..	Dg	40	6×8	..	Sandstone, grey, current-bedded.
45	S. edge of Sardarganj.	Sindhu Resettlement Corporation.	Dr.	60	6"	L	(?)
46	0.5 mile ESE of Viri.	..	Dg	41	8×7	BM	Sandstone, coarse Trap, jointed.

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Manchhar	Top of concr. platform.	0	47·29	Mar. 3.	I	88	Yields 12 gal./min. with drawdown of 19·2 ft. after pumping 15 min. Use in conjunction with Shinaya water for irrigation. Water has brackish taste.
Do.	..	..	..	Do.	P	88	Yields 20 gal./min. Water has brackish taste.
Do.	..	..	..	Do.	P	89	Yields 30 gal./min. by 4-inch turbine pump.
Do.	Top of casing	1·0	48·45	Do.	Un	..	
Do.	Top of platform	1·7	21·85	Mar. 4.	P	..	Curbed masonry 0-22 ft.+
Upper Bhuj(?)	Top of curb, E. side.	0	96·20	Do.	Un	..	Curbed SS. blocks 0-15 ft.
Lower Bhuj	Top of curb, E. side.	2·0	62·15	Do.	I	84	Irrigates 1½ acres. Water sufficient for 2 motes except in summer months. Water has slightly brackish taste.
Do.	Lip of SS. slab, W. side.	1·5	33·75	Do.	I	83	Water sufficient for one mote. Water has markedly brackish taste. Curbed SS. blocks 0-5 ft. Irrigates wheat.
Upper Bhuj	Top of curb, N. side.	0	34·60	Do.	Un	..	No curbing.
Do.	Top of SS. curb, SE. side.	1·7	9·95	Mar. 5	P	..	Curbed SS. blocks 0-18 ft.+
Do.	Top of curb, N. side.	0	10·73	Do.	Un	..	Curbed SS. masonry 0-4 ft. Water has moderately good taste.
Do.	Lip of SS. slab, E. side.	0	14·38	Do.	I	..	Curbed rubble masonry 0-10 ft. Irrigation use part of year.
Manchhar	Top of curb, N. side.	0	38·66	Mar. 6	D	..	Curbed SS. blocks 0-6 ft. Water has brackish taste.
Do.	Top of curb, W. side.	0	31·70	Do.	I	..	Water has brackish taste.
Do.	Ground level .	0	10+	Do.	..	87	Pumped at 10 gal./min. with single action lift pump. Water is salty. Used for construction purposes.
Manchhar (?) Deccan	Lip of SS. slab, N. side.	1·0	12·42	Mar. 8	I	..	Yields sufficient water for one mote.

APPEN

Hydrologic data for wells in the Anjar

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
47	0·62 mile SW of Viri.	Hamir Malla Koli.	Dg	34	13×8	BM	Sandstone
48	0·75 mile SW of Viri.	.	Dg	34	15×9	..	Do.
49	1·0 mile SW of Viri	..	Dg	29	..	..	Sandstone, argillaceous.
50	1·0 mile SW of Viri	..	Dg	35	10×6	..	Do.
51	0·2 mile WSW of Viri	Teja Sewji	Dg	27	11×8	BM	Sandstone
52	0·2 mile W. of Viri	Jiva Natha	Dg	36	11×6	BM	Do.
53	0·25 mile W. of Viri	..	Dg,B	61	6×6 & 6"(?)	BM	Do.
54	0·3 mile W. of Viri	Bhawan Patel	Dg	34	10×7	BM	Do.
55	0·4 mile W. of Viri	Lalji Wasta	Dg	35	8×9	BM	Do.
56	0·42 mile W. of Viri	Khora Nepa Mistry.	Dg,B	39	12×6	BM	Sandstone, coarse.
57	Just S. of Viri	..	Dg	17	6×8	..	Trap, decomposed jointed.
58	Just S. of Viri	..	Dg	27	14×10	..	Trap, jointed & Sandstone, coarse.

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj	Lip of SS. slab, E. side.	1·0	17·38	Mar. 12	I	..	Irrigation use part of year. Water has slightly brackish taste.
Do.	Lip of SS. slab, E. side.	..	16·85	Mar. 13	Un	..	Curbed trap blocks 0-17 ft. Water has good taste.
Do.	Lip of SS. slab, N. side.	..	23·50	Do.	Un	..	
Do.	Top concrete block, NW corner.	..	17·70	Do.	Un	..	Curbed trap blocks 0-5 ft.
Do.	Lip of SS. slab, E. side.	1·0	14·75	Do.	I	..	Irrigates 6 acres. Water drawn for 6 hrs./ day throughout year. Water generally sufficient for one mote. Curbed SS. blocks 0-10 ft.
Do.	Lip of SS. block, E. side.	..	25·51	Mar. 14	I	..	Water drawn for 8 hrs./ day through most of year by 2 motes. Curbed trap blocks 0-25 ft.+ Well begins in trap and ends in sandstone.
Do.	Do.	2·0	23·42	Do.	I	86	Water drawn for 4 hrs./ day (aver.) by one mote to irrigate 3 acres. Curbed SS. blocks 0-11 ft. Water has good taste. Dug 86 ft. then bored 45 ft.
Do.	Top of curb, NE corner.	..	21·74	Do.	I	85	Water drawn for about 8 hrs./day by one mote to irrigate about 4 acres. Curbed SS. blocks 0-15 ft. Water has good taste.
Do.	Lip of SS. slab, W. side.	1·0	19·90	Do.	I	85	Water drawn for about 8 hrs./day by one mote to irrigate 2¼ acres. Curbed SS. blocks 0-12 ft. Water has good taste.
Do.	Edge of SS. slab, W. side.	0	21·09	Do.	I	83	Water drawn for about 8 hrs./day by 2 motes to irrigate 3 acres. One bore hole of unknown depth in bottom of dug well. Curbed SS. blocks 0-8 ft.
Deccan	Lip of SS. slab, SW side.	0	11·60	Mar. 15	Un	..	Curbed 0-6 ft. Water has slightly brackish taste.
Deccan & Upper Bhuj	Lip of SS. slab, SE side.	..	15·70	Do.	Un	..	Water has good taste.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
59	..	Jivan Ratna	Dg	33	10×8	BM	Sandstone
60	0·75 mile SW of Viri.	Mahanji	Dg	36	9×8	DM	Do.
61	0·75 mile WSW of Viri.	Narsi Arja	Dg	34	11×8	BM	Do.
62	0·6 mile WSW of Viri.	Hirawala	Dg	41	10×11	BM	Do.
63	0·6 mile WSW of Viri.	..	Dg	30	5×5	..	Sandstone, coarse
64	0·2 mile W. of Viri.	..	Dg	31	12×7	BM	Do.
65	0·37 mile W. of Viri	Bhimji Raghu Mistry.	Dg	42	14×8	BM	Sandstone
66	0·5 mile W. of Viri	Jiva Natha	Dg	51	17×6	BM	Do.
67	1·25 miles WSW of Viri.	..	Dg	35	8×6	..	Do.
68	1·25 miles WSW of Viri.	..	Dg	31	10×8	..	Do.
69	0·37 mile SSW of Viri.	..	Dg	28	10×10	..	Trap, jointed and decomposed.
70	0·75 mile NNW of Anjar.	Devaram Lalji	Dg,B	33†	21×9	BM	Trap, jointed & sandstone (?).
71	1·0 mile NNW of Anjar.	Dhanji Lalji	Dg,B	44†	9×9	BM	Sandstone
72	1·0 mile NNW of Anjar.	Ladharam Khemji.	Dg	56	15×15	BM	Sandstone, argillaceous.

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj	Lip of SS. slab, N. side.	0	18·43	Mar. 15.	I	85	Water drawn for about 8 hrs./day by one mote. Curbed 0-18 ft.+
Do.	Top of curb, E. side.	..	15·85	Mar. 16	I	85	Water drawn for about 6 hrs./day by one mote to irrigate 3 acres.
Do.	Lip of SS. slab, N. side.	..	18·90	Do.	I	82	Irrigates 3 acres by one mote. Curbed 0-8 ft. Water has slightly brackish taste.
Do.	Edge of SS. slab, E. side.	..	25·93	Do.	I	86	Trap 0-15 ft. and sandstone below. Water drawn for about 8 hrs./day by one to 2 motes to irrigate about 3½ acres. Water has good taste.
Do.	Edge of SS. slab	0	22·70	Do.	Un	..	No curbing.
Do.	Lip of SS. slab, W. side.	0	20·90	Do.	I	84	Irrigates about 3 acres by 2 motes. Curbed SS. blocks 0-15 ft. Water has good taste.
Do.	Lip of SS. slab, E. side.	..	26·20	Do.	I	..	Curbed SS. blocks 0-15 ft. Water has good taste.
Do.	Edge of curb, E. side.	..	29·76	Do.	I	86	Water drawn by 2 to 4 motes for about 7 hrs./day. Curbed SS. blocks 0-30 ft.† Water has good taste.
Do.	Lip of SS. slab, S. side.	..	21·55	Mar. 17	I	..	Curbed SS. blocks 0-3 ft. Water has fair taste.
Do.	Lip of SS. slab, NE corner.	0	21·58	Do.	Un	..	Curbed SS. blocks 0-5 ft. Water has good taste.
Deccan	Edge of curb, E. side.	3·0	11·31	Do.	I	..	Irrigation use part of year. Water has good taste.
Deccan and Upper Bhuj (?)	Lip of SS. slab, E. side,	..	19·97	Mar. 18	I	82	Irrigates about 3 acres with one mote. Bored hole in 33 ft. dug well. Curbed SS. blocks 0-20 ft.† Water has brackish taste.
Upper Bhuj	Lip of SS. slab, E. side.	1·0	34·99	Do.	I	83	Water drawn about 8 hrs./day to irrigate 2½ acres by 2 motes. Supply inadequate. Curbed SS. blocks 0-35 ft.+ One boring in 44 ft. dug well. Water has good taste.
Do.	Edge of wooden platform, S. side.	..	39·64	Do.	I	83	Water drawn about 8 hrs./day to irrigate 4 acres by 2 motes. Curbed masonry 0-40 ft.+ Water has slightly brackish taste.

Hydrologic data for Wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
73	1·12 miles NNW of Anjar.	Rewa Shankar .	Dg	42	12×12	BM	Sandstone
74	1·12 miles WNW of Anjar.	..	Dg	49	19×15	BM	Do.
75	1·0 mile NNW of Anjar.	Jiwaram Maran	Dg	44	10×3	BM	Sandstone (?)
76	1·5 mile W. of Viri	..	Dg	44	7×7	..	Sandstone, argillaceous
77	1·0 mile W. of Anjar.	Megha Patel	Dg	51	9×7	..	Sandstone .
78	1·0 mile W. of Anjar.	Shamji Shewji	Dg,B	52+	11×7	..	Sandstone, grey .
79	Do.	Do.	Dg,B	100	14×10 & 6″	HC	Sandstone .
80	0·75 mile N. of Sardarganj.	..	Dg	24	9×9	..	Alluvium (?) .
81	0·87 mile W. of Anjar.	Mangalgar Bau	Dg	64	10×7	..	Sandstone .
82	Do.	Warjang Khemji	Dg	61	14×10	HC	Do.
83	0·6 mile N. of Khedoi Mota.	Deoji Bhima	Dg,B	38+	14×9	BM	Do.
84	Do.	..	Dg	43	13×12	HC	Sandstone, cross-bedded, argillaceous.
85	0·6 mile N. of Khedoi Mota.	..	Dg	39	9×7	BM	Sandstone.

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk,* eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 8	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj	Lip of SS. slab, NE. side.	..	25·65	Mar. 18	I	82	Water drawn about 8 hrs./day to irrigate about 2½ acres by one or 2 motes. Curbed masonry 0-26 ft.+
Do.	Lip of SS. slab, NW. side.	..	30·61	Do.	I	..	Curbed SS. blocks 0-10 ft. Irrigation use part of year.
Do.	Lip of SS. slab .	..	28·15	Do.	I	83	Curbed SS. blocks 0-28 ft.+ Water drawn about 8 hrs. /day to irrigate 1½ acres by one or 2 motes. Water has slightly brackish taste.
Do.	Lip of SS. slab, SW. side.	1·0	36·46	Mar. 19	Un	..	Step well. Curbed SS. blocks 0-10 ft. Water has fair taste.
Do.	Lip of center SS. slab S. side.	0	44·02	Do.	I	..	Curbed SS. blocks 0-10 ft. Water has brackish taste.
Do.	Lip of proj. SS. slab, W. side.	..	42·00	Mar. 24	I	..	Irrigation use part of year. Water has good taste. One boring of unknown depth in dug well. Curbed SS. blocks 0-10 ft.
Do.	Lip of proj. SS. slab, E. side.	0	45·15	Do.	I	84	Well yields 300 gal./min. and is pumped about 8 hrs./day throughout year to irrigate 12 acres. Water has good taste. Curbed 0-10 ft.
Recent-	Lip of proj. SS. slab S. side.	..	14·00	Mar. 26	P	..	Curbed SS. blocks 0-14 ft. Water has slightly brackish taste.
Upper Bhuj	Edge of curb, SE side.	1·0	55·00	Mar. 27	Un	..	Curbed 0-6 ft. Water has brackish taste.
Do.	Lip of SS. slab, W. side.	..	48·47	Do.	I	..	Water has good taste.
Do.	Lip of SS. block, S. side.	0	24·48	Mar. 28	I	83	Water drawn by 1 to 4 motes for about 8 hrs./day throughout year to irrigate 8 acres. Water has good taste.
Do.	Lip of proj. SS. slab, E. side.	0	20·10	Do.	I	..	Curbed 0-10 ft.
Do.	Edge of curb, N. side.	..	17·64	Do.	I	..	Water drawn by 1-2 motes for about 8 hrs./day throughout year. Water has slightly alkaline taste.

APPEN

Hydrologic data for Wells in the Anjar-

Well No.	Location	Owner	Type [1]	Depth (feet)	Dimensions (feet)	Method of lift [2]	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
86	1·12 miles W. of Anjar.	Anandji	Dg, B	120	12×10 & 6"	HC	Sandstone
87	1·12 miles W. of Anjar.	Shewji Nanji	Dg	58	23×9	HC	Sandstone, coarse.
88	1·12 miles WNW of Anjar.	Narsi Deoji	Dg, B	133	17×9	HC	Sandstone
89	1·25 miles WNW of Anjar.	Rathor Dosa	Dg, B	131 & 6"	13×8	HC	Do.
90	0·5 mile E. of Nagalpur Mota.	Shewji Shamji	Dg	40	12×7	..	Do.
91	Do.	Harji Gangadas	Dg, B	50+	13×7	HC	Sandstone, argillaceous.
92	0·62 mile E. of Nagalpur Mota.	Deoram Gangji	Dg	50	11×6	BM	Sandstone
93	Do.	Mistry Ratnardas.	Dg	53	14×8	HC	Do.
94	0·62 mile N. of Khedoi Mota.	Shomji Meghji	Dg	44	12×8	BM	Do.
95	0·75 mile N. of Khedoi Mota.	Popat Nersi	Dg, B	166+	9×12 & 6"	HC	Do.
96	0·25 mile SW of Anjar.	Manaklal	Dg	48	16×14	BM	Sandstone, yellowish brown, soft.

See footnote at end of table.

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use[3]	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj	Lip of SS. block, E. side.	..	42·23	Mar. 29	I	83	Pumped 8 to 12 hrs./day throughout year to irrigate 6 acres. Water has good taste. Dug to 60 ft. then three 60-foot borings in bottom.
Do.	Edge of curb, E. side.	..	49·19 (pumping)	Do.	I	85	Well yields 260 gal./min. and is pumped about 8 hrs./day through most of year to irrigate several acres.
Do.	Lip of proj. SS. slab, S. side.	..	45·49	Do.	I	85	Pumped 8 to 12 hrs./day throughout year to irrigate 10-11 acres. Dug to 62 ft. then one boring 70 ft. deep in bottom. Water has good taste.
Do.	Lip of proj. SS. sla, E. side.	..	51·27 (pumping)	Do.	I	86	Well yields 280 gal./min. and is pumped about 8 hrs/day throughout year to irrigate several acres. Dug 61 feet then one boring 80 ft. deep in bottom. Water has good taste.
Do.	Lip of proj. SS. slab, S. side.	..	33·90	Apr. 1	Un	..	Water brackish taste.
Do.	Lip of proj. SS. slab, E. side.	0	35·01	Apr. 4	I	85	Well yields 260 gal./min. with 5 ft. drawdown after 3½ hrs. pumping. Pumped about 8 hrs./day through most of year to irrigate several acres. Dug 50 ft. then one boring of unknown depth in bottom. Water has good taste. Curbed 0-12 ft.
Do.	Edge SS. curb, W. side.	..	34·91	Apr. 3	I	..	
Do.	Lip of proj. SS. slab, E. side.	..	35·48	Do.	I	..	Irrigates about 5 acres. Curbed 0-20 ft.
Do.	Lip of SS. slab, E. side.	..	21·98	Apr. 4	I	..	Water is slightly brackish.
Do.	Lip of SS. slab, E. side.	1·0	33·02 Recovering	Do.	I	..	Yields 280 gal./min. with 12-ft. drawdown after 4 hrs. pumping. Irrigates about 6 acres. Dug 41 ft. then 2 bores approx. 125 ft. deep in bottom. Curbed 0-11 ft. Water has good taste.
Do.	Lip of SS. slab, S. side.	1·0	32·20	Apr. 23	I	..	Irrigates 2 acres by one mote. Curbed 0-23 ft. Water is slightly brackish.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type[1]	Depth (feet)	Dimensions (feet)	Method of lift[2]	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
97	1·50 miles WSW of Viri.	..	Dg	19	5×5	..	Trap .
98	2·5 miles ENE of Khedoi Mota.	..	Dg	24	5	..	Fractured trap .
99	0·2 mile N. of Anjar.	Khem Chand .	Dg, B	62	13×6 & 6″	BM	Sandstone .
100	0·1 mile NW of Anjar.	Premji Paddu .	Dg	54	9×11	BM	Do.
101	0·35 mile WSW of Anjar.	Dayaram .	Dg, B	106	12×9 & 6″	BM	Sandstone, pale grey.
102	0·5 mile WSW of Anjar.	Prabulal Pranjivan.	Dg	61	15×14	BM	Sandstone .
103	1·0 mile SW of Anjar.	Govand Jiva .	Dg	59	14	HO	Sandstone, yellow, soft.
104	Do.	Ramdasji .	Dg, B	48†	10	HO	Sandstone .
105	Do.	Panchan Moorji	Dg, B	82	25×27 & 6″	BM	Sandstone, soft, yellowish, grey.
	0·25 mile SW of Anjar.	Khemj Ratna .	Dg	59	11×9	BM	Sandstone .

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	Remarks
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Deccan	Lip of SS. slab, S. side.	2·0	12·77	Apr. 24	S	..	Water has good taste. Curbed 0-13 ft.† Step well.
Do.	Top of curb	0·5	15·41	Do.	S,P	..	Curbed 0-16 ft.5* Water has good taste.
Upper Bhuj	Lip of SS. curb, S. side.	0	27·46	Apr. 25	I	87	Irrigates about 3 acres, with one to 3 motes. Dug 37 ft. then 2 borings about 25 ft. deep in bottom. Curbed 0-25 ft.† Water has good taste.
Do.	SS. slab, SW. side	..	36·58	Do.	I	84	Well begins in trap and ends in sandstone.
Do.	Lip of SS. slab, center E. side.	2·0	41·97	Apr. 26	I	83	Irrigates 2 acres by one to 2 motes working 6 hrs./day through year. Curbed 0-9 ft. Water has good taste. Dug 56 ft. then one boring 40 ft. deep in bottom.
Do.	Lip of SS. slab, center W. side.	2·0	46·82	Do.	I	85	Water drawn about 6 hrs./day through year by 1 to 2 motes to irrigate about 2½ acres.
Do.	Lip of SS. slab, center S. side.	4·0	49·21	Do.	I	86	Pumped at 82 gal./min. for about 8 hrs./day and about 11 months/yr. to irrigate 3 acres. Drawdown about 7 ft. after 8 hrs. pumping. Water has good taste. Curbed 0-12 ft.
Do.	Lip of SS. slab, NW. side.	0	28·34	Do.	I	84	Pumped at 152 gal./min. for 4 hrs./day throughout year to irrigate 4 acres. Dug 48 ft. then one boring of unknown depth. Water has very slightly brackish taste. Curbed 0-28 t.
Do.	Lip of SS. slab, SE. corner.	3·0	22·54	Do.	I	83	Water drawn by one to 2 motes about 10 hrs./day and 11 months/year. Dug to 42 ft. then one boring 40 ft. deep in bottom. Curb d 0-22 ft. Water has slightly brackish taste
Do.	Lip of SS. flag, center of E. side.	4·0	39·46	Do.	I	88	Irrigates 2 acres by one to 2 motes which work about 6 hrs./day for 11 months/year. Water has good taste.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
107	0·25 mile W. of Anjar.	Ramdas . .	Dg	58	15×13	BM	Sandstone . .
108	0·1 mile S. of Anjar	Sambhu Jetha .	Dg,B	100	19×11 & 6"	HC	Sandstone, yellowish grey, soft.
109	Do.	Yussef Bhadani	Dg	51	10×8	BM	Sandstone (?) and Trap.
110	0·5 mile WSW of Antarjal.	..	Dg	45	9×7	..	Sandstone, micaceous.
111	0·62 mile SW of Antarjal.	..	Dg	43	7×5	..	Sandstone
112	1·0 mile S. of Antarjal.	..	Dg	54	8×6	..	Sandstone, fine to coarse, yellowish grey.
113	1·0 mile NNW of Viri.	Hasam . .	Dg	23	7×7	BM	Sandstone, silty .
114	0·75 mile E. of Sidungra.	..	Dg	42	6×6	..	Sandstone, grey .
115	1·0 mile SW of Viri.	..	Dg	28	..	..	Sandstone . .
116	0·82 mile SSE of Mota Nagalpur.	..	Dg	27	9×7	..	Sandstone, grey .
117	0·75 mile SSE of Mota Nagalpur.	Abdullah Gandhi	Dg	25	9×8	BM	Sandstone . .
118	Do.	Hussein Perdan	Dg	33	14×10	BM	Sandstone, grey .

See footnotes at end of table.

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	Remarks
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj	Top of curb, center of S. side.	0	34·48	Apr. 26	I	87	Irrigates 5 acres by one to 3 motes which work about 8 hrs./day for 11 months/year. Curbed 0-35 ft.† Water has good taste.
Do.	Lip of SS. slab, center of E. side.	0	42·38	Do.	I	86	Pumped at 165 gal./min. for about 8 hrs./day through year to irrigate about 10 acres. Dug 50 ft. then one boring 50 ft. deep bottom. Water has good taste.
Bhuj (?) and Deccan	Top of curb, center of W. side.	2·2	19·40	Do.	I	82	Irrigates about 2 acres by one to 3 motes. Water has good taste.
Manchhar	Lip of slab, center of S. side.	1·0	29·74	Apr. 30	I	..	Irrigation use part of year. Water has slightly brackish taste.
Do.	Lip of SS. slab, center of W. side.	2·0	36·77	Do.	I	..	Irrigation use part of year. Water has slightly brackish taste. Curbed 0-6 ft.
Do.	Lip of SS. slab, center of N. side.	5·0	33·57	Do.	I	82	Irrigation use part of year. Water has slightly brackish taste. Curbed 0-15 ft.
Upper Bhuj	Lip of SS. slab, center of N. side.	1·0	15·30	May 3	I	83	Irrigates about one acre by one mote. Water has good taste. Curbed 0-5 ft.
Do.	Top of SS. curb, W. side.	0	29·70	Do.	Un	..	Step well. Water has good taste.
Do.	Top of curb, SE corner.	0	26·84	May 6	Un	..	
Do	Top of SS. slab, center of E. side.	1·0	23·68	May 9	Un	..	Curbed 0-12 ft.
Do.	Top of curb, center of S. side.	0	15·70	Do.	I	83	Irrigates 4 acres by one to 2 motes which work about 8 hrs./day for about 11 months/year. Water has good taste. Curbed 0-16 ft.
Do.	Top of curb, E. side.	2·0	22·27	Do.	I	85	Irrigates 6 acres by one to 2 motes which work about 8 hrs./day for about 11 months/year. Water has good taste. Curbed 0-14 ft.

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
119	2·5 miles NE of Khedoi Mota.	Bhagat Bali Bauri (temple).	Dg	84	5	..	Sandstone, brown and grey.
120	1·1 miles ENE of Khedoi Mota.	..	Dg	49	11×6	..	Sandstone, yellowish grey, friable.
121	0·6 mile E. of Khedoi Mota.	..	Dg	53	9×6	..	Sandstone, coarse silty.
122	E. side of Khedoi Mota.	..	Dg	39	8×7	..	Trap, jointed and sandstone.
123	0·15 mile SW of Khedoi Mota.	..	Dg	21	5×6	..	Trap . .
124	0·12 mile W. of Khedoi Mota.	Hirji Dunji .	Dg	39	10×17 × 17×9	BM	Sandstone, yellowish brown.
125	W. side of Khedoi Mota.	Moti Bhai .	Dg, B	106	8×5 & 6″	BM	Sandstone . .
126	3·25 miles ENE of Khedoi Mota.	..	Dg	36	6×6	..	Trap . .
127	0·75 mile WNW of Khedoi Mota.	Abu Galeria .	Dg	44	10×6	BM	Sandstone, coarse, argillaceous, white.
128	2·25 miles WNW of Khedoi Mota.	Pachan Walji .	Dg	64	4	..	Sandstone . .
129	0·25 mile S. of Loharia.	Viram . .	Dg, B	142	9×7 & 6″	BM	Do.
130	0·32 mile S. of Pantia.	Govind Khanji	Dg	51	10×8	BM	Sandstone, yellowish grey.
131	0·75 mile S. of Kidana.	..	Dg	17	10×5	..	Sandstone . .

See footnotes at end of table.

DIX—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use §	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj	Top of curb, E. side.	1·0	73·82	May 9	P	85	Water has good taste. Curbed 0-13 ft.
Do.	Top of SS. slab, center of W. side.	1·0	34·97	May 10	Un	..	Curbed 0-9 ft.
Do.	Top of SS. slab, center of S. side.	2·0	27·96	Do.	Un	..	Curbed 0-1
Deccan and Upper Bhuj	Top of SS. slab, center of E. side.	0	27·63	May 11	Un	..	Curbed 0-2 ft.
Deccan	Top of curb, N. side.	2·0	13·67	Do.	P	..	Curbed 0-14 ft.† Water has good taste.
Upper Bhuj	Top of SS. slab, S. side.	2·0	19·09	Do.	I	81	Irrigates 4 acres by one to 4 motes. Water has brackish taste. Curbed 0-12 ft.
Do.	Top of SS. slab, center of S. side.	3·0	28·37	Do.	I	85	Irrigates 1½ acres by one mote. Dug 46 ft. (0-15 ft., trap; 15-46 ft., sandstone) then one boring. 50 ft. deep in bottom. Water has brackish taste. Curbed 0-15 ft.
Deccan	Top of concrete curb, E. side.	0·8	19·87	May 12	P	..	Curbed 0-20 ft.† Water has good taste.
Upper Bhuj	Top of curb, S. side.	3·0	26·90	Do.	I	83	Irrigates 2 acres by one to 2 motes working about 8 hrs./day for 6 months/year. Water has fair taste. Curbed 0-5½ ft.
Do.	Top of curb, N. side.	2·5	55·30	Do.	P	85	Curbed 0-10 ft. Water has good taste.
Do.	Lip of chute, center of S. side.	3·0	40·22	Do.	I	85	Irrigates 5 acres by one to 2 motes working about 8 hrs./day for 11 months/year. Dug 52 ft. then one boring 90 ft. deep in bottom. Curbed 0-12 ft. Water has good taste.
Do.	Top of SS. slab, center E. side.	1·0	34·13	Do.	I	86	Irrigates 3 acres by one mote. Curbed 0-8 ft. Water has good taste.
Manchhar	Top of SS. slab, center E. side.	2·0	10·43	May 13	I	81	Irrigation use part year. Water has moderately brackish taste. Curbed 0-5 ft.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type [1]	Depth (feet)	Dimensions (feet)	Method of lift [2]	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
132	1·62 miles SSE of Shinaya.	..	Dg	22	8×9	..	Sandstone . .
133	1·75 miles SSE of Shinaya.	..	Dg	27	8×6	..	Sandstone . .
134	1·5 miles SSE of Shinaya.	..	Dg	27	7×4	..	Trap, disintegrated
135	0·5 mile S. of Shinaya.	Bikha Ratana .	Dg	25	8×7	BM	Trap, amygdaloidal, soft.
136	1·62 miles SSE of Shinaya.	Topia Wala Quan.	Dg	23	12×8	..	Sandstone . .
137	0·25 mile SE of Shinaya.	..	Dg	22	9	BM	Trap, jointed .
138	0·12 mile SE of Shinaya.	..	Dg	41	8×10	BM	Trap, amygdaloidal, soft.
139	0·62 mile E. of Shinaya.	Argun . .	Dg	38	9×8	BM	Trap . .
140	0·25 mile SW of Shinaya.	Vasta Jiva .	Dg	44	8×7	BM	Trap, nodular, soft
141	0·5 mile SW of Shinaya.	..	Dg	40	8×5	BM	Trap, spheroidal .
142	1·0 mile SW of Shinaya.	..	Dg	45	10×8	BM	Do.
143	1·0 mile WSW of Shinaya.	Mepa Lada .	Dg	46	9×10	BM	Trap, fractured .
144	2·0 miles SW of Shinaya.	Naran Patel .	Dg	19	6×6	..	Trap . .
145	3·0 miles WNW of Shinaya.	..	Dg	10	6	..	Trap, dense .
146	2·75 miles WNW of Shinaya.	..	Dg	13	11	..	Trap . .

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk,* eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	Remarks
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Manchhar	Top of curb, N. side.	0	12·63	May 14	P	..	Curbed 0-1 ft. Water has sulphurous odour and brackish taste.
Do.	Lip of SS. chute, E. side.	2·0	14·45	Do.	I	..	Irrigation use part of year. Very little water. Water has good taste.
Deocan	Lip of SS. chute, E. side.	2·0	12·08	May 16	I	80	Curbed 0-4½ ft. Water has good taste. Irrigation use part of year.
Do.	Top of SS. slab, S. side.	..	15·75	Do.	I	..	Irrigates about 2 acres by one mote working about 6 hrs./day for 8 months/year. Water has brackish taste. Curbed 0-14 ft.
Upper Bhuj	Top of curb, N. side.	..	9·94	Do.	P	82	Curbed 0-6 ft. Water has brackish taste.
Daccan	Top of SS. chute, E. side.	1·0	18·75	Do.	I	80	Curbed 0-10 ft. Water has brackish taste. Irrigation use part of year.
Do.	Top of SS. slab, E. side.	1·0	27·16	Do.	I	..	Irrigation use part of year. Curbed 0-13 ft. Water has brackish taste.
Do.	Top of SS. block, E. side.	0	13·57	Do.	I	85	Curbed 0-14 ft. Water has slightly brackish taste.
Do.	Top of SS. slab, E. side.	1·0	21·32	Do.	I	83	Irrigates one acre by one mote. Water has brackish taste. Curbed 0-6 ft.
Do.	Top of SS. slab, E. side.	4·0	27·97	May 17	I	86	Irrigates 1½ acres by one to 2 motes. Curbed 0-11 ft. Water has very slightly brackish taste.
Do.	Top of SS. slab, center E. side.	2·0	18·68	Do.	I	..	Irrigation use part of year. Curbed 0-9½ ft. Water has brackish taste.
Do.	Top of SS. slab, center E. side.	2·0	26·72	Do.	I	..	Irrigates 2 acres by one to 2 motes. Water has good taste. Curbed 0-16 ft.
Do.	Lip of SS. chute, E. side.	0	16·43	Do.	Un	..	Water has brackish taste and sulphurous odour. Log: Manchhar sandstone 0-13 ft.: trap 13-19 ft.
Do	Top of curb, S. side.	0·5	8·25	May 18	Un	..	Water has salty taste. Curbed 0-7½ ft.
Do.	Top of curb, N. side.	1·0	4·54	Do.	P	..	Water has good taste. Curbed 0-4 ft.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
147	1·75 miles WNW of Shinaya.	Govan Devira .	Dg	24	8×12	..	Trap, jointed, hard
148	2·12 miles WNW of Shinaya.	..	Dg	30	12×6	..	Trap . .
149	1·0 mile SW of Reladi Mota.	..	Dg	86	9×7	..	Sandstone . .
150	0·5 mile NNE of Bhajodi.	Manji Jeram .	Dg	40	4×6	..	Sandstone, white, argillaceous.
151	2·5 miles WSW of Bhuj.	.. .	Dg	94	12×10	..	Sandstone, yellowish brown.
152	0·5 mile W. of Mirjapur.	..	Dg	65	10×7	..	Do.
153	0·25 mile E. of Naranpur.	Kurj Kanji ,	Dg, B	69+ & 6"	12×7	HO	Sandstone . .
154	2·75 miles N. of Bharapur.	Kutch State Sanitorium.	Dg	56	9×10	HO	Do.
155	0·5 mile NE of Warsamedi.	Kanji Bisram .	Dg	18	11	BM	Sandstone, medium to coarse, grey.
156	0·6 mile NNW of Khara Paswalia.	..	Dg	31	8	BM	Sandstone, mottled
157	0·4 mile SE of Satapur.	Wasta Vehama	Dg	22	11	BM	Sandstone (?) .
158	0·6 mile SW of Khamra.	..	Dg	36	7×5	..	Sandstone . .
159	0·3 mile E. of Mota Nagalpur.	..	Dg	41	12×6	..	Do.
160	1·8 miles SW of Anjar.	..	Dg	42	10×10	..	Sandstone, grey .
161	1·5 miles NE of Mota Nagalpur.	Ratna Nara .	Dg	54	12×7	BM	Sandstone . .
162	1 mile ENE of Sidungra.	Parbat Vira .	Dg, B	55	13×21	BM	Do.

See footnote at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk,* eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Deccan	Lip of SS. slab, E. side.	0·5	18·20	May 18	I	..	Irrigation use part of year. Water has good taste. Curbed 0-6 ft.
Do.	Top of SS. slab, center E. side.	2·0	18·09	Do.	I	..	Irrigation use part of year. Water has brackish taste. Curbed 0-11 ft.
Upper Bhuj (?)	Top of SS. slab, W. side.	2·0	77·81	May 23	P	83	Water has good taste. Curbed 0-12 ft.
Do.	Top of SS. chute, E. side.	0	34·96	Do-	Un	..	Water has good taste. Curbed 0-35 ft.†
Do.	Top of SS. slab, N. side.	1·0	86·09	Do.	Un	..	Water has good taste Curbed 0-4 ft.
Do.	Top of SS. slab, center N. side.	0	56·48	Do.	Un	..	Water has slightly brackish taste. Curbed 0-11 ft.
Do.	Top of SS. slab, center E. side.	2·0	53·12	Do.	I	85	Yields 800 gal./min. approx. by pump. Dug 69 ft. then one boring of unknown depth.
Lower Bhuj (?)	Top of concrete wall, E. side.	3·0	43·11	Do.	P	..	Water has good taste. Curbed 0-13 ft.
Manchhar	Top of SS. chute, NE side.	1·0	11·18	May 30	I	..	Irrigation use part of year. Water has slightly brackish taste. Curbed 0-12 ft.
Do.	Lip of SS. slab, W. side.	3·0	13·54	Do.	I	..	Irrigation use part of year. Water has very brackish taste. Curbed 0-14 ft.†
Do.	Top of timber, S. side.	0	14·74	May 31	I	..	Water has salty taste.
Upper Bhuj	Top of SS. slab, E. side.	1·0	30·90	June 5	..	..	Curbed 0-3 ft.
Do.	Lip of SS. slab, S. side.	3·0	36·03	Do.	I	..	Water has good taste. Curbed 0-18 ft.
Do.	Lip of SS. slab, E. side.	2·0	32·68	June 6	I	..	Water has good taste. Curbed 0-13 ft. Irrigation use part of year.
Do.	Lip of proj. SS. slab, E. side.	1·0	43·91	June 7	I	..	Worked 8 hrs./day for 11 months a year by one mote. Irrigates 4 acres. Curbed SS. blocks 0-10 ft. Water has good taste.
Do.	Lip of SS. slab, SE side.	1·0	32·77	Do.	I	..	Irrigates 5 acres by 2 motes worked 10 hrs./day for 10 months a year. One boring at the bottom of the well, depth not known. Water has brackish taste.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type[1]	Depth (feet)	Dimensions (feet)	Method of lift[2]	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
163	0·8 mile NE of Khamra.	Ramji Hardas .	Dg	53	9×13	BM	Sand stones, yellowish brown.
164	0·5 mile WNW of Khamra.	..	Dg	43	×6	..	Sandstone, silty, yellowish brown.
165	0·1 mile E. of Khamra.	Ladda Ram Kheta	Dg, B	200	11×8	..	Sandstone, pale brown.
166	0·5 mile SE of Pantia.	..	Dg	40	6×6	..	Sandstone, current bedded, grey.
167	0·3 mile W. of Pantia.	Kanji Premji .	Dg	51	9×6	..	Sandstone, yellow grey.
168	1 mile NNE of Khedoi Mota.	..	Dg	40	8×6	..	Sandstone, grey .
169	Khirasra . .	Ransore Gala .	Dg, B	89	10×8	BM	Do.
170	0·4 mile NE of Loharia.	..	Dg	38	8×7	..	Sandstone, silty, grey.
171	0·4 mile WSW of Loharia.	..	Dg	34	8×6	..	Sandstone, grey .
172	1·25 miles NNW of Khedoi Mota.	Himmat Singh .	Dg, B	38	11×8	HO	Do.
173	0·25 mile N. of Khedoi.	Karmsingh Govinda.	Dg	34	13×7	..	Sandstone, yellowish brown and grey.
174	1 mile NNW of Khedoi Mota.	Bhoj Rajji Shesh Malji.	Dg	29	9×8	MB	Sandstone, pale brown.

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use	Temperature (F°) 3	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj	Lip of middle proj. SS. slab, E. side.	1·0	39·23	June 9	I	85	Irrigates 5 acres by 4 motes, working 8 hrs./day for 11 months/year. Water clean and has good taste. Produces millet. wheat and vegetables.
Do.	Lip of middle proj. ISS. slab, E. side.	1·0	31·49	Do.	Un	82	Turbid, bad smelling water with good taste.
Do.	Do.	1·0	32·10	Do.	Un	..	Has a clean very slightly brackish water which is not good for irrigation. Dug 50 ft. and then two open bores of 150 ft. Observation well.
Do.	Lip of proj. SS. slab on the N. side, arrow mark.	0	37·65	Do.	Un	84	Step well. Curbing 0-5 ft. Observation well.
Do.	Lip of middle SS. slab, E. side.	1·0	35·91	Do.	Un	..	Well out of use since 6 years. Curbed 0 to 6·5 ft. Water has bad smell but good taste. Observation well.
Do.	Lip of middle SS. slab, S. side, arrow mark.	1·0	22·49	June 10	Un	83	Curbed 0 to 9 ft. Water has clean good taste. Observation well.
Do.	Lip of middle SS. slab, E. side, arrow mark.	0	28·96	June 11	I	86	Irrigates 6 acres by 2 motes working 10 hrs./day for 10 months/year. Dug 44 ft. then open bore 45 ft. deep. Water has clean and good taste. Produces wheat, millet and vegetables.
Do.	Lip of middle SS. slab, E. side.	1·0	28·31	Do.	I	..	Irrigates 2 acres by one mote, seasonally. Curbed 0-13 ft. Water has good taste.
Do.	Arrow on SS. slab, E. side.	0·5	30·31	Do.	Un	85	Curbed 0-4 ft. Water clean and has good taste.
Do.	Lip of SS. slab, E. side.	2·0	26·82	Do.	I	86	Yield 170 gal./min. 6 hrs./day 10 months/year, irrigate 8 acres. Curbed 0-13 ft. Has a clean good taste water.
Do.	Lip of SS. slab, E. side.	2·0	22·93	Do.	I	83	Irrigation use part of year for millet. Curbed 0-12 ft.
Do.	Lip of SS. slab, S. side at arrow mark.	1·0	24·23	Do.	I	86	Irrigates 4 acres by one mote works 8 hrs./day for 10 months/year. Curbed SS. blocks 0-18 ft. Water not enough for one mote.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
175	0·5 mile S. of Mota Nagalpur.	Ratnar Das	Dg	44	12×9	MB	Grey sandstone and white siltstone.
176	0·5 mile NE of Khedoi Mota.	Apji, Shivji	Dg	34	10×9	MB	Grey sandstone and siltstone.
177	0·9 mile NNE of Khedoi Mota.	Sutar Harji Harijan.	Dg, B	95	17×6	HC	Grey brown sandstone.
178	0·6 mile N. of Viri	Dara Jatt.	Dg	81	10×7	MB	Trap
179	0·9 mile N. of Viri	Hasim Omer Jatt	Dg	54	9×7	MB	Trap, jointed
180	0·8 mile NNW of Viri.	Jusuf Mithu	Dg	38	11×7	MB	Do.
181	1 mile SSW of Anjar.	..	Dg	14	..	..	Sandstone
182	0·6 mile SW of Anjar.	Raja Mula	Dg	41	8×10	MB	Do.
183	0·5 mile SW of Anjar.	Hari Ramji Ebji.	Dg, B	150	13×6	MB	Do.

See footnotes at end of table.

DIX—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj	Lip of middle SS. slab, E. side at arrow mark.	2·0	23·82	June 18	I	82	Irrigation use part of year for millet. Water has very slightly brackish taste. Curved 0-12 ft. Observation well.
Do.	Lip of middle SS. slab, S. side, arrow mark.	3·0	20·99	Do.	I	82	Irrigation use seasonal for millet crop after rains. Worked by two motes. Curbed 0-18 ft. Water has good taste. Observation well.
Do.	Do.	1·0	26·56	Do.	I	..	Yields 380 gal./min. for 8 hrs./day, 10 months/year and irrigates 6 acres of land. Dug 45 ft. then open 4" bore 50 ft. deep. Curbed 0-6 ft. Water has good taste and irrigates wheat, millet and vegetables.
Deccan	Lip of SS. slab, E. side.	4·0	23·60	June 20	I	88	Irrigates 1¼ acres by one mote working 4 hrs./day for 10 months/year. Water has good taste and irrigates mango and palm gardens. Yield not sufficient for one mote. Curbed 0-7 ft.
Do.	Lip of SS. slab, SE. side.	0	36·76	Do.	I	88	Irrigates fruit trees in 3 acres of land, by 2 motes working 8 hrs./day for 10 months/year. Curbed 0-10 ft. Water has good taste.
Do.	Lip of SS. slab, E. side.	9·0	20·75	June 23	I	88	Yields sufficent water for 2 motes. Irrigates 4 acres by 2 motes working 6 hrs./day for 11 months/year. Irrigate wheat, millet and fruit trees. Curbed 0-11 ft.
Upper Bhuj	Top of SS. curbing.	0	11·34	Do.	Un	85	Abandoned well. No curbing.
Do.	Lip of mid. wooden plank, E. side.	2·0	21·82	Do.	I	86	Irrigates 2 acres by 2 motes, working 8 hrs./day for 10 months/year. Water has good taste. Curbed 0-22 ft.
Do.	Lip of mid. SS. slab, E. side.	2·0	34·1	Do.	I	84	Irrigates 5 acres by 3 motes working 8 hrs./day for 10 months/year. Water has good taste. Produce millet, wheat and vegetables. Curbed 0-34 ft.

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
184	0·4 mile SW of Anjar.	Daya Shankar Shyamji.	Dg, B	67	13×7	MB	Sandstone, white .
185	0·6 mile SW of Anjar.	Ramji Abu .	Dg	64	10×6	MB	Sandstone .
186	0·5 mile SW of Anjar.	Devchand Hirji	Dg, B	74	14×9	MB	Do.
187	0·5 mile WSW of Anjar.	Hira Bhai Lalji	Dg	63	14×12	MB	Do.
188	0·5 mile WSW of Anjar.	Swami Narain .	Dg	59	10×15	MB	Do.
189	0·4 mile SW of Anjar.	Jata Shankar .	Dg	61	11×11	MB	Do.
190	0·4 mile SW of Anjar.	Do.	Dg, B	145	9×7	MB	Do.
191	0·25 mile SW of Anjar.	Ram Das Morarji.	Dg, B	93	9×7	MB	Do.
192	0·25 mile SW of Anjar.	Ram Hadda .	Dg, B	118	12×7	MB	Do.

See footnotes at end of table.

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level: Measuring Point: Description	Water Level: Measuring Point: Above land surface (feet)	Water Level: Depth to water (feet)	Water Level: Date of measurement (1951)	Use 8	Temperature (F°)	REMARKS
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj	Lip of SS. slab, SE. side.	2·0	43·98	June 23	I	84	Irrigates 4 acres by 3 motes working 10 hrs./day for 11 months a year. Water has good taste. Curbed 0-10 ft.
Do.	Mid. SS. slab, SE. side.	2·0	41·07	June 25	I	85	Irrigates 2 acres by one mote working 10 hrs. day for 11 months/year Curbed 0-11 ft. Water slightly brackish. Produces wheat and millet, not suitable for vegetables.
Do.	Lip of SS. slab, SW. side.	2·0	35·26	Do.	I	86	Irrigates 2 acres by 2 motes working 10 hrs./day, 11 months/year. Dug 55 ft. then open bore 18 ft. deep. Water has good taste. Curbing 0-14 ft.
Do.	Lip of mid. SS. slab, NW. side.	1·0	41·36	Do.	I	84	Irrigates 3 acres by 2 motes working 9 hrs./day for 11 months/year. Curbing 0-19 ft. Water has good taste. Produces wheat, millet and vegetables.
Do.	Lip of mid. SS. slab, E. side.	1·0	41·06	Do.	I	84	Irrigates 5 acres by 4 motes working 10 hrs./day for 10 months/year. Curbed 0-10 ft. Produces wheat, millet and vegetables.
Do.	Lip of mid. SS. slab, SW. side.	1·0	39·88	Do.	I	83	Irrigation use for garden. Curbing 0-12 ft.
Do.	Do.	2·0	44·20	Do.	I	83	Irrigates 3 acres by 2 motes working 10 hrs./day for 11 months/year. Dug 55 ft. then open 2 bores 90 ft. deep. Curbing 0-10½ ft. Water has good taste.
Do.	Lip of mid. SS. slab, SE. side.	2·0	43·82	June 27	I	84	Irrigates one acre by 2 motes working 9 hrs./day for 11 months/year. Dug 58 ft. then 2 open bores 40 ft. deep each. Curbing 0-9 ft.
Do.	Do.	1·0	41·99	Do.	I	85	Irrignte 4 acres by 2 motes working 10 hrs./day for 11 months/year. Dug 58ft. then 2 open borings 60 ft. deep Curbing 0-9 ft. Water has good taste.

Hydrologic data for wells in the Anjar -

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
193	0·25 mile SW. of Anjar town.	Raghavji Akhai	Dg, B	158	13×13	MB	Sandstone . .
194	0.24 mile SW. of Anjar town.	Deva Pancha .	Dg	61	13×11	MB	Grey sandstone .
195	0.12 mile SW. of Anjar town.	Ilias Abba .	Dg	58	10×12	MB	Grey sandstone, silty at places.
196	Do.	Do. .	Dg	61	11×8	MB	Sandstone . .
197	0·8 mile SWS. of Anjar.	..	Dg	23	..	BM	Do.
198	0·06 mile S. of Anjar.	Chandar Das .	Dg	66	11×7	HC	Do.
199	0·07 mile S. of Anjar.	Kanji Manikchand.	Dg	62	17×7	HC	Do.
200	0·08 mile S. of Anjar.	Meghji . .	Dg	55	20	BM	Do.
201	0·09 mile S. of Anjar.	Dhanji Jehta .	Dg	50	11×8	..	Do.
202	0·11 mile S. of Anjar.	Do.	Dg	55	13½	BM	Do.
203	0·15 mile S. of Anjar.	Sunderji Shivji	Dg	54	9×7	BM	Do.

See footnotes at end of table.

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj	Lip of mid. SS. slab, NW side.	1·0	41·95	June 27	I	83	Irrigate 2 acres by 2 motes, working 10 hrs./day for 11 months/year. Dug 58 ft. then 2 open bores 100 ft. deep each. Curbing 0-13 ft. Water has good taste.
Do.	Lip of mid. SS. slab, E. side.	3·0	42·80	Do.	I	84	Irrigate 2½ acres by 2 motes, working 10 hrs./day for 11 months/year. Enough water for two motes. Water has a good taste. Produces wheat, millet and vegetables.
Do.	Lip of mid. SS. slab, SE. side.	1·0	41·20	Do.	I	85	Irrigate 2 acres by 2 motes, working 10 hrs/day for 10 months/year. Curbed 0-10 ft.
Do.	Top of curb, NE. side.	4·0	42·44	Do.	I	85	Irrigate 2 acres by 2 motes, working 10 hrs./day for 10 months/year. Curbed 0-14 ft. Water has good taste. Produces wheat, millet and vegetables.
Do.	Lip of mid. slab, E. side.	0	11·28	June 28	Un	84	Water has brackish taste.
Do.	Lip of Mid. SS. slab, E. side.	1·0	42·62	Do.	I	86	Irrigate 4 acres by pumping 160 gal./min. for 10 hrs./day and 10 months/year. Curbed 0-10 ft. Water has good taste.
Do.	Lip of mid. SS. slab, N. side.	0	49·50	Do.	I	86	Irrigates 12 acres by pumping 170 gal./min. for 12 hrs./day and 11 months/year. Curbing 0-10 ft. Water has good taste.
Do.	Lip of mid. SS. slab, S. side.	2·0	40·65	Do.	I	85	Irrigates 3 acres by 2 motes, working 8 hrs./day for 10 months/year. Water has good taste Produces wheat, millet and vegetables.
Do.	Lip of mid. SS. slab, E. side.	2·0	41·44	Do.	Un	..	Water has bad smell and brackish taste. Curbed 0-15 ft.
Do.	Lip of mid. SS. slab, N. side.	1·0	39·55	Do.	S	82	Sometimes used for irrigation.
Do.	Do.	1·0	42·42	Do.	I	84	Irrigates 2 acres by one mote, working 10 hrs./day for 10 months/year. Curbing 0-27 ft. Water has good taste. Produces wheat, millet and vegetables

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
204	0·16 mile S. of Anjar.	Jata Shankar .	Dg	58	12×12	BM	Sandstone . .
205	0.17 mile S. of Anjar.	Tumbak Lal Moti Ram.	Dg	58	11×10	HC	Do.
206	0·12 mile SW. of Anjar.	Udhav Ji .	Dg	57	14×11	BM	Do.
207	0·8 mile W. of Anjar.	Daya Shankar Shyam Ji.	Dg	57	12×12	BM	Do.
208	Do.	Dhan Ji Kuwarji	Dg	60	11×9	BM	Do.
209	0·84 mile W. of Anjar.	Bala Dola .	Dg	57	9×11	BM	Do.
210	0·86 mile W. of Anjar.	Girdhar Das .	Dg	55	10×8	BM	Do.
211	0·8 mile SW. of Anjar.	Prabhu Lal Nandavana.	Dg	43	12×11	BM	Do.
212	0·8 mile WSW. of Anjar.	Do.	Dg	48	9×6	..	Do.
213	0·9 mile WSW. of Anjar.	..	Dg	47	10×9	..	Do.
214	0·9 mile SW. of Anjar.	..	Dg	44	9×11	..	Do.
215	0·05 mile W. of Anjar.	..	Dg	39	11×9	..	Jointed basalts.
216	0·05 mile W. of Anjar.	Temple Well .	Dg	29	10×8	..	Do.

See footnotes at end of table

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj	Lip of mid. SS. slab, E. side.	1·5	40·85	June 28	I	84	Irrigates 8 acres by 3 motes, working 10 hrs./day for 11 months/year. Water has a very slight brackish taste.
Do.	Do.	1·0	45·04	Do.	I	84	Irrigates 6 acres by HC. Yields 140 gal./min. working 10 hrs./day for 10 months/year. Water has good taste. Produces wheat, millet and vegetables.
Do.	Lip of mid. slab, N. side.	1·0	46·17	Do.	I	83	Irrigate about 3 acres. Curbing 0-13 ft.
Do.	Lip of mid. SS. slab, SE. side.	2·0	40·08	June 29	I	85	Irrigate 5 acres by 4 motes, working 9 hrs./day for 10 months/year. Water has good taste. Curbing 0-12 ft.
Do.	Lip of mid. SS. slab, E. side.	2·0	42·31	Do.	I	86	Irrigates 2½ acres by 2 motes, working 9 hrs./day for 10 months/year. Water has good taste. Curbed 0-26 ft.
Do.	Depression bet. 2 proj. SS. slabs, W. side.	2·0	42·93	Do.	I	85	Irrigates 2 acres by one mote, working 9 hrs./day, for 11 months/year. Curbed 0-17 ft.
Do.	Lip of mid. proj. SS. slab, W. side.	2·0	44·92	Do.	I	84	Irrigates 8 acres by 2 motes, working 9 hrs./day for 11 months/year. Water has good taste. Curbed 0-14 ft.
Do.	Lip of mid. proj. SS. slab, N. side.	2·0	29·03	Do.	I	86	Irrigates 2 acres by 2 motes, working 9 hrs./day for 11 months/year. Water has good taste. Curbed 0-11 ft.
Do.	Lip of mid. proj. SS. slab, E. side.	0	35·38	Do.	Un	85	Curbed 0-8 ft. Water has good taste.
Do.	Lip of mid. proj. SS. slab, NE. side.	0	40·54	Do.	Un	84	Water has good taste. Curbed 0-13 ft.
Do.	Lip of mid. proj. SS. slab, E. side.	1·0	32·08	Do.	Un	84	Water has good taste. Curbed 0·11 ft.
Deccan trap	Lip of proj. SS. slab, E. side.	2·5	16·19	July 2	D	..	Pale yellow colour water with good taste.
Do.	Lip of SS. slab, N. side.	3·0	16·46	Do.	D	..	Water has good taste. Curbed 0-10 ft.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type[1]	Depth (feet)	Dimensions (feet)	Method of lift[2]	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
217	0·01 mile W. of Anjar.	Temple Well .	Dg	36	7×7	..	Jointed basalts .
218	0·2 mile W. of Anjar.	Nan Ji Kan Ji	Dg	38	12×6	BM	Do.
219	0·17 mile W. of Anjar.	Madhorao temple	Dg	64	20×12	BM	Sandstone . .
220	0·24 mile W. of Anjar.	Man Ji Mur Ji .	Dg	50	7	..	Jointed Basalts .
221	0·46 mile W. of Anjar.	Val Ji Prem Ji .	Dg, B	210	12×12 and 6″	BM	Sandstone . .
222	0·4 mile W. of Anjar.	Manjal Ji .	Dg	58	10×7	BM	Do.
223	0·41 mile W. of Anjar.	Jamuba . .	Dg	46	..	BM	Do.
224	0·4 mile W. of Anjar.	Bacher Bhawan	Dg, B	157	19×11 and 6″	HC	Do.
225	0·48 mile W. of Anjar.	Municipalty Well.	Dg	52	12	..	Jointed Basalts .
226	0·64 mile W. of Anjar.	Do.	Dg	88	12	..	Do.
227	0·02 mile E. of Anjar.	Bachaha . .	Dg	68	13	MB	Sandstone . .
228	0·05 mile E. of Anja	Jiva Bhai .	Dg	61	14	BM	Do.
229	Just W. of Eastern wall of Anjar.	Ratan Singh .	Dg, B	115	16	HC	Do.

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region. Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Deccan	Depression bet. the 2 proj. SS. slab, N. side.	1·0	19·98	July 2	S	..	Water slightly brackish.
Do.	Mid. proj. SS. slab, N. side.	0	23·6	Do.	I	..	Irrigation use for 2 months after rains.
Upper Bhuj	Mid. space bet. 2 proj. SS. slabs, N. side.	1·0	47·47	Do.	I	..	Irrigates 5 acres by 4 motes, working 10 hrs./day for 11 months/year. Curbed 0-15 ft.
Deccan	Top of curb. N. side.	2·0	32·88	Do.	D	..	Water has good taste.
Upper Bhuj	Mid. proj. SS. slab, E. side.	0	43·39	Do.	I	..	Irrigates 3 acres by 2 motes. Dug 60 ft. and then 3 borings one 150 ft. and other two 100 ft. deep. Water has good taste.
Do.	Mid. SS. slab, E. side.	2·0	45·44	Do.	I	..	Irrigates 2 acres by 2 motes, working 10 hrs./day for 11 months/year. Water has good taste.
Do.	Tin plate E. side	0	41·68	Do.	I	..	Well irrigates by one mote, working 10 hrs./day for 11 months/year. Water has good taste.
Do.	Mid. proj. SS. slab, E. side.	1·0	40·34	July 7	I	..	Irrigates 5 acres, working 6 hrs./day for 10 months/year. Yields 130 gal./min. Dug 61 ft. and then two borings each 96 ft. deep. Water has good taste.
Deccan	From wooden fencing lying just above the curbing.	2·0	46·11	Do.	D	..	Water has good taste. Curbed 0-15 ft.
Do.	From wooden fencing lying just above the curbing.	2·0	31·66	Do.	Un	..	Curbed 0-16 ft.
Upper Bhuj	Mid. proj. SS. slab, W. side.	0	39·50	July 8	I	..	Irrigates 6 acres by 4 motes, working 10 hrs/day for 10 months/year. Water has good taste.
Do.	Mid. proj. SS. slab, S. side.	1·0	35·03	Do.	I	87	Irrigates 5½ acres by 4 motes, working 9 hrs/day for 10 months/year Water has good taste.
Do.	Mid. proj. SS. slab, S. side.	1·0	41·96	Do.	I	88	Irrigates 13 acres by HO, working 10 hrs./day for 10 months/year. Well dug 55 ft. and bored 60 ft. deep. Water has good taste.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
230	0·02 mile E. of Anjar.	Kara Manak Chand.	Dg	48	11	BM	Sandstone . .
231	0·05 mile E. of Anjar.	Prabhu Lal .	Dg	56	15×13	BM	Do.
232	Do.	Jata Shankar Dosa.	Dg	54	16×16	BM	Do.
233	0·08 mile E. of Anjar.	Narain Ratna .	Dg	54	15×13	BM	Do.
234	0·15 mile E. of Anjar.	Amar Singh .	Dg	32	10×9	..	Jointed basalt .
235	0·2 mile SE. of Anjar.	Anandji Vishnuji.	Dg	46	..	BM	Do.
236	0·1 mile N. of Anjar.	Baldoo Das .	Dg, B	74	15×12	BM	Sandstone . .
237	Do.	Triku Kheta .	Dg	80	12	BM	Do.
238	0·05 mile N. of Anjar.	Murar Bhai .	Dg	27	10	BM	Do.
239	Just N. of Boundary Wall around Anjar.	Kutch Govt. .	Dg	34	15×10	..	Do.
240	0·04 mile N. of Anjar.	Morar Bhai .	Dg	30	10	BM	Do.
241	0·01 mile N. of Anjar.	Thakarji Ranthor Das.	Dg	47	11×16	BM	Jointed basalts .
242	Just E. of Nagalpur	Wallsh Patel .	Dg	44	12×11	BM	Sandstone . .

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS.
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj	Mid. proj. SS. slab, E. side.	1·0	28·82	July 8	I	88	Irrigates 2 acres by 2 motes, working 6 hrs./day for 10 months/year Water has good taste. Produces wheat, millet and vegetables.
Do.	Mid. SS. slab, E. side.	1·0	33·17	July 10	I	80	Irrigates 5 acres by 4 motes, working 9 hrs./day for 10 months/year. Curbed 0-13 ft. Water has good taste.
Do.	Mid. SS. slab, W. side.	1·0	31·00	Do.	I	86	Irrigates 7 acres by 4 motes, working 8 hrs./day for 10 months/year Curbed 0-15 ft. Water has good taste. Produces wheat and millet.
Do.	Mid. proj. SS. slab, E. side.	1·0	27·45	Do.	I	88	Irrigates 5 acres by HO, working 4 hrs./day for 6 months/day. Yields 180 gallons/min. Water has good taste.
Deccan trap	Mid. SS. slab, W. side.	2·0	24·09	Do.	D	84	Curbed 0-9 ft.
Do.	Proj. wooden block SE. corner.	0	12·08	Do.	D	88	
Upper Bhuj	Mid. proj. SS. slab, W. side.	1·0	25·16	July 13	I	85	Irrigates 3 acres by 2 motes, working 9 hrs./day for 10 months/year. Dug 44 ft. and then bored 30 ft. deep. Water has good taste.
Do.	Mid. proj. SS. slab, E. side.	1·0	19·42	Do.	I	88	Irrigation by 2 motes, working 8 hrs./day for 10 months/year. Water has good taste.
Do.	Do.	0	15·97	Do.	I	88	Irrigates by 2 motes, working 8 hrs./day for 10 months/year.
Do.	Mid. proj. SS. block, E. side.	1·0	19·02	Do.	Un	..	Curbed 0-9 ft. Turbid unclean water.
Do.	Lip of SS. slab, N. side.	2·0	18·75	Do.	I	87	Irrigates 4 acres by 2 motes, working 10 hrs./day for 10 months/year. Water has good taste.
Deccan	Lip of proj. SS. slab, N. side.	4·5	12·19	Do.	D	85	Water used for making ice. Water has good taste.
Upper Bhuj	Lip of mid. proj. SS. slab, N. side.	1·0	31·28	July 17	I	83	Irrigates 1½ acres by 2 motes for 2 months a year. Curbed 0-12½ ft.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
243	Just E. of Nagalpur	Molu Maman	Dg	45	10×7	BM	Sandstone
244	1·3 miles W. of Anjar.	Raja Vasta	Dg	47	16×17	BM	Do.
245	1·35 miles W. of Anjar.	Koja Kasam Ali	Dg	44	10×7	BM	Do.
246	1·4 miles W. of Anjar.	Khoja Abdul Dasi.	Dg	42	9×7	BM	Do.
247	1·5 miles W. of Anjar.	Khoja Kasam Ali Sulaman.	Dg	40	10×7	BM	Do.
248	1·35 miles W. of Anjar.	Do.	Dg	117	10×10	BM	Do.
249	1·18 miles W. of Anjar.	..	Dg	50	18×9	BM	Do.
250	1·45 miles WSW. of Anjar.	..	Dg	40	13×7	..	Do.
251	1·2 miles W. of Anjar.	..	Dg	45	14×9	BM	Do.
252	1·28 miles WSW. of Anjar.	Walla Raja	Dg	46	..	BM	Do.
253	1·45 miles WSW. of Anjar.	..	Dg	41	..	..	Do
254	1·6 miles SW. of Anjar.	Khoja Ratani	Dg	29	15×9	BM	Do.
255	Do.	Khoja Fajal Datu.	Dg	28	7×10	BM	Do.
256	1·7 miles SW. of Anjar.	Kara Gorji	Dg	27	15×15	BM	Do.

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj	Lip. of Mid. proj. SS. slab, E. side.	1·0	31·55	July 17	I	85	Irrigates 1·5 acres by 2 motes, working 9 hrs./day for 10 months/year. Curbed 0-17 ft. Water has slightly brackish taste.
Do.	Lip of SS. slab, E. side.	1·0	35·97	July 18	I	81	Seasonal irrigation by 4 motes. Curbed up to water level. Water slightly brackish.
Do.	Do.	1·0	35·35	Do.	I	83	Seasonal irrigation. Curbed 0-20 ft. Slightly brackish water.
Do.	Lip of mid. proj. SS. slab, W. side.	2·0	34·38	Do.	I	88	Seasonal irrigation. Slightly brackish water. Produces millet only.
Do.	Lip of mid. proj. SS. slab, E. side.	0	34·23	Do.	I	83	Seasonal irrigation. Water slightly brackish.
Do.	Lip of SS. slab, N. side.	3·0	40·64	Do.	I	84	Irrigation by 2 motes, working 8 hrs./day for 10 months/year. Dug 47 ft. and then 2 borings one 70 ft. and the other 40 ft. deep.
Do.	Lip of Mid. SS. slab, E. side.	0	35·68	Do.	I	84	Seasonal irrigation. Curbed 0-14 ft.
Do.	Lip of mid. SS. slab, N. side.	0	30·25	Do.	Un	85	Curbing 0-3·5 ft. Water has good taste.
Do.	Mid. proj. SS. slab, E. side.	1·0	35·76	July 24	I	83	Seasonal irrigation by 2 motes. Curbing 0-15 ft. Water has good taste.
Do.	Mid. proj. SS. slab, N. side.	0	34·11	Do.	I	86	Irrigates 2 acres by 2 motes, working 10 hrs./day for 10 months/year. Water has good taste. Produces wheat, millet and vegetables.
Do.	Mid. proj. SS. slab, E. side.	0	29·85	Do.	Un	85	Water has good taste. No uniform curbing.
Do.	Mid. proj. SS. slab, N. side.	2·0	20·01	Do.	I	83	Seasonal irrigation. Curbed 0-11 ft. Water has good taste.
Do.	Mid. proj. SS. slab, E. side.	0	17·15	Do.	I	85	Seasonal irrigation by one mote. Curbed 0-9 ft.
Do.	Mid. proj. SS. slab, N. side.	3·0	16·62	Do.	I	85	Seasonal irrigation by one mote. Water has good taste. Curbed 0-14 ft.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
257	0·6 mile SE of Anjar.	Bandali Hirji Khoja.	Dg, B	78	12×14	BM	Sandstone . .
258	1·2 miles W. of Anjar.	Moolji Ladhu .	Dg, B	116	9×7	HC	Do.
259	1·3 miles W. of Anjar.	Mistry Vihsanji Nathu.	Dg	50	11×7	HC	Do.
260	Do.	Manji Anda .	Dg	60	12×7	HC	Do.
261	Do.	Arjun Bhimji .	Dg, B	110	9×7	HC	Coarse sandstone
262	1·2 miles WNW. of Anjar.	Madhavji Shivji.	Dg, B	129	14×9	HC	Sandstone with thin shales.
263	1·25 miles WNW. of Anjar.	Kantilal Ranchhor.	Dg, B	158	15×16	HC	White coarse grained, pebbly sandstones.
264	1·15 miles WNW. of Anjar.	Harji Shivji .	Dg, B	157	10×8	HC	Sandstone . .
265	1·4 miles WNW. of Anjar.	Ramji Dev Raj.	Dg, B	145	12×7	HC	Do.

See footnotes at end of table.

Khedoi region, Anjor *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 8	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1952)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj	Lip of SS. slab, S. side.	1·0	18·76	July 24	I	84	Irrigates 6 acres by 4 motes, working 10 hrs./day for 10 months/year. Dug 38 ft. and then 2 open borings 40 ft. deep each.
Do.	Lip of SS. slab, E. side.	1·0	47·59	July 25	I	85	Irrigates 10 acres by HC, working 8 hrs./day for 10 months/year. Yield 140 gals./min. Curbed 0-11 ft. Water has good taste.
Do.	Lip of Mid. proj. SS. slab, W. side.	1·0	47·60	Do.	I	85	Irrigates about 10 acres by HC, working 8 hrs./day for 10 months/year. Water has good taste. Produces wheat, millet and vegetables.
Do.	SS. slab, E. side	1·0	53·77	Do.	I	86	Irrigates 5 acres by HC, working 8 hrs./day for 10 months/year. Water has good taste. Curbed 0-14 ft.
Do.	Mid. proj. SS. slab E. side.	1·0	48·55	Do.	I	86	Irrigates 4 acres by HC, working 8 hrs./day for 10 months/year. Yield 50 gals./min. Curbing 0-11 ft. Water has good taste.
Do.	Mid. proj. SS. slab, W. side.	0	58·35	Do.	I	87	Irrigates 2 acres by HC, not sufficient water for the pump. Dug 59 ft. and then one boring 70 ft. deep. Good taste milky water.
Do.	Top of parpet wall, E. side.	2·0	55·41	July 29	I	86	Irrigates 7 acres by HC, working 9 hrs./day for 8 months/year. Dug 78 ft. and then one open boring 75 ft. deep. Water has good taste.
Do.	Lip of SS. slab, E. side.	0	49·32	Do.	I	86	Irrigates 5 acres by HC, working 6 hrs./day for 10 months/year. Yielding 90 gals./min. Dug 67 ft. and then bored 90 ft. deep. Good taste water.
Do.	Lip of mid. proj. SS. slab, W. side.	1·0	49·48	Do.	I	85	Irrigates 10 acres. Dug 65 ft. and then one open boring 80 ft. deep. Water has good taste. Produces wheat, millet and vegetables.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
266	1·45 miles W. of Anjar.	Hirji Dhanji	Dg, B	99	9×8	BM	Sandstone
267	0·7 mile NE. of Mota Nagalpur.	Ramji Dosa	Dg, B	134	14×7	HO	Do.
268	1·32 miles W. of Anjar.	Raja Vasta	Dg, B	104	17×9	HO	Do.
269	0·6 mile NE. of Mota Nagalpur.	Sava Bhai	Dg, B	131	14×10	HO	Do.
270	0·6 mile NE. of Mota Nagalpur.	Hari Lal Hirji	Dg, B	100	10×9	BM	Do.
271	0·4 mile NE. of Mota Nagalpur.	Madhanji Raghu	Dg, B	54	17×10	BM	Do.
272	0·25 mile NE. of Mota Nagalpur.	Khoja Fajil	Dg	48	12×9	BM	Do.
273	0·05 mile NE. of Mota Nagalpur.	Narsi Dosa	Dg	51	16×9	HO	Do.
274	0·3 mile NE. of Mota Nagalpur.	Shaymji Bhimji	Dg	50	9×13	BM	Do.
275	0·2 mile NE. of Mota Nagalpur.	Do.	Dg	51	13×16	BM	Do.

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj	Lip. of mid. proj. SS. slab, E. side.	1·0	42·85	July 20	I	83	Irrigates 6 acres by 2 motes, working 8 hrs./day for 10 months/year. Water has good taste. Curbed 0-7 ft.
Do.	Lip. of mid. proj. SS. slab, S. side.	1·0	41·84	Do.	I	85	Irrigates 9 acres by HC, working 8 hrs./day for 10 months/year. Dug 54 ft. and one boring 80ft. deep. Yields 126 gals./min. Good taste water.
Do.	Lip. of mid. proj. SS. slab, W. side.	1·0	43·68	Aug. 3	I	84	Irrigates 8 acres by H C, working 11 hrs./day for 11 months/year. Dug 54 ft. then open boring 50 ft. deep. Curbing 0-18 ft. Water has good taste.
Do.	Lip. of mid. proj. SS. slab, E. side.	1·0	45·75	Do.	I	85	Irrigates 6 acres by HC, working 12 hrs./day for 11 months/year. Dug 55 ft. and then one boring 76 ft. deep. Curbed 0-9 ft. Good taste water.
Do.	Do.	2·0	44·11	Do.	I	85	Irrigates 4 acres by 2 motes working 10 hrs./day for 11 months/year. Curbed 0-7 ft. Water has good taste.
Do.	Lip. of proj. SS. slab, E. side.	3·0	43·55	Do.	I	84	Irrigates 3 acres by one mote working 10 hrs./day for 10 months/year. Curbed 0-8 ft. Produces wheat, millet and vegetables.
Do.	Mid. proj. SS. slab, E. side.	2·0	37·38	Aug. 4	I	83	Irrigates 2 acres by 2 motes working 8 hrs./day for 10 months/year. Curbed 0-10 ft. Water has good taste. Produces wheat, millet and vegetables.
Do.	Do.	1·0	45·07	Do.	I	83	Irrigates 8 acres working 8 hrs./day for 10 months/year. Yields 170 gals./min. Curbed 0-8 ft. Water has good taste.
Do.	Mid. proj. SS. slab, N. side.	1·0	38·09	Do.	I	82	Irrigates by 2 motes working 8 hrs./day for 10 months/year. Curbed 0-31 ft.
Do.	Do.	2·0	39·16	Do.	I	83	Irrigation by 4 motes working 8 hrs./day for 10 months/year. Curbed 0-13 ft. Water has good taste.

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
276	0·2 mile NE. of Mota Nagalpur.	Ranchhor Kanji	Dg, B	143	15×10	BM	Sandstone . . .
277	0·1 mile N. of Mota Nagalpur.	Govind Bhima	Dg	47	10×8	BM	Do.
278	Just E. of Mota Nagalpur.	Kanji	Dg	48	10×9	BM	Do.
279	0·1 mile of Mota Nagalpur.	Bhanji Shivji	Dg	50	13×9	HC	Do.
280	Just E. of Mota Nagalpur.	Pancham Moorji	Dg	46	7×7	..	Do.
281	0·1 mile W. of Mota Nagalpur.	Manji	Dg	47	11×8	BM	Do.
282	0·2 mile NW. of Mota Nagalpur.	Abdullah	Dg	52	12×10	BM	Do.
283	0·2 mile W. of Mota Nagalpur.	Sulaman Bardali Patel.	Dg	35	14×10	BM	Do.
284	0·1 mile W. of Mota Nagalpur.	Amar Singh	Dg	38	11×9	BM	Do.
285	0·05 mile W. of Mota Nagalpur.	Dhanji Ratna	Dg, B	46	11×10	BM	Do.

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use [3]	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj.	Mid. proj. SS. slab, E. side.	1·0	41·60	Aug. 4	I	85	Irrigates 2 acres by 2 motes working 10 hrs./day for 10 months a year. Dug 52 ft. and then one boring 90 ft. deep. Curbed 0-9 ft.
Do.	Lip of SS. slab, W. side.	2·0	39·41	Do.	I	83	Irrigates 1¼ acres by 2 motes working 10 hrs./day for 10 months/year. Water has good taste. Produces wheat and millet.
Do.	Lip of mid. proj. SS. slab, E. side.	1·0	37·66	Do.	I	84	Irrigates 3 acres by one mote, working 10 hrs./day for 10 months/year Water has good taste. Produces wheat, bajr. and vegetables.
Do.	Lip of Mid. proj. SS. slab, W. side.	2·0	37·17	Aug. 5	I	83	Irrigates 4 acres by H working 5 hrs./day for 4 months/year. Curbing 0·8 ft. Produces wheat and millet but not suitable for vegetables.
Do.	Wooden plank	2·5	33·45	Aug. 11	D	83	Curbed 0-14 ft. Water is clean and has good taste.
Do.	Mid. proj. SS. slab, E. side.	1·0	38·15	Do.	I	86	Irrigates 2 acres by 2 motes, working 10 hrs./day for 10 months/year. Water has good taste. Produces wheat, millet and vegetables.
Do.	Lip of mid. proj. SS. slab, E. side.	2·0	35·42	Do.	I	84	Irrigates 3 acres by 3 motes, working 10 hrs./day for 10 months/year. Curbed 0-12 ft. Water has good taste.
Do.	Do.	2·0	22·94	Do.	I	85	Irrigates 1·5 acres by 3 motes, working 10 hrs./day for 10 months/year. Curbing 0-9 ft. Water has good taste.
Do.	Do.	2·0	27·73	Do.	I		Irrigates 2 acres by 2 motes, working 10 hrs./day for 10 months/year. Curbed 0-12 ft. Produces wheat, millet and vegetables.
Do.	Do.	1·0	30·53	Do.	I	84	Irrigation by one mote. Curbed 0-13 ft. Water has good taste. Produces wheat, millet and vegetables.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type [1]	Depth (feet)	Dimensions (feet)	Method of lift [2]	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
286	0·1 mile W. of Mota Nagalpur.	Amina Bai	Dg	40	14×9	BM	Sandstone
287	0·45 mile SSW of Mota Nagalpur.	Hirji Rajpal	Dg	29	10×9	BM	Do.
288	0·4 mile SSW of Mota Nagalpur.	Bandali Datu	Dg	51	10×8	BM	Do.
289	0·3 mile S. of Mota Nagalpur.	..	Dg	37	9×8	BM	Do.
290	0·25 mile S. of Mota Nagalpur.	Dhanji Rautna	Dg	29	14×10	BM	Do.
291	0·2 mile S. of Mota Nagalpur.	..	Dg	32	16×13	BM	Do.
292	0·2 mile SSW of Mota Nagalpur.	..	Dg	45	13×8	BM	Do.
293	0·13 mile SSW of Mota Nagalpur.	Kasim Patel	Dg	38	..	BM	Do.
294	0·3 mile SW of Mota Nagalpur.	Kasu Khoja	Dg	140	9×8	BM	Do.
295	0·35 mile SW of Mota Nagalpur.	Khengar Leera Bhai.	Dg	34	10×9	BM	Do.

see footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)			8		
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj.	Edge of Mid. proj. SS. slab, E. side.	1·0	29·40	Aug. 11	I	84	Irrigates 5 acres by 3 motes, working 10 hrs./day for 10 months/year. Water has good taste. Produces wheat, millet and vegetables.
Do.	Lip of proj. SS. slab, E. side.	1·0	21·02	Aug. 12	I	84	Irrigates 3 acres by one mote. Working 10 hrs./day for 10 months/year. Produces wheat, millet and vegetables. Curbed 0-9 ft.
Do.	Lip of mid. SS. slab, N. side.	1·0	20·62	Do.	I	83	Seasonal irrigation. Curbed 0·9 ft. Water has slightly brackish taste.
Do.	Lip of mid. SS slab, E. side.	1·0	19·95	Do.	I	84	Seasonal irrigation by one mote. Water has good taste. Curbed 0-11 ft. Produces millet.
Do.	Lip of SS. slab, S. side.	2·0	23·54	Do.	I	84	Irrigates garden by 2 motes, working 10 hrs./day for 10 months/year. Curbed 0-11 ft. Water has slightly brackish taste.
Do.	Lip of mid SS. slab, N. side.	2·0	20·92	Do.	I	83	Irrigation by 2 motes working 10 hrs./day for 10 months/year. Water has good taste. Curbing 0-14 ft.
Do.	Lip of mid. SS. slab, E. side.	1·0	24·12	Do.	I	85	Garden irrigation by 2 motes, working 10 hrs./day for 10 months/year. Curbing 0-10 ft. Water has good taste.
Do.	Lip of SS. slab, E. side.	1·0	24·65	Do.	I	84	Garden irrigation by two motes, working 10 hrs./day for 10 months/years. Curbed 0-3 ft. Water has good taste.
Do.	Lip of mid. SS. slab, E. side.	1·0	18·22	Do.	I	85	Irrigates 5 acres by 2 motes, working 10 hrs./day for 10 months/year. Dug 40 ft. and one boring 100 ft. deep.
Do.	Lip of SS. slab, E. side.	3·0	21·25	Do.	I	84	Irrigates 4 acres by 2 motes, working 10 hrs./day for 10 months/year. Water has good taste. Curbed 0-9 ft. Produces wheat, millet and vegetables.

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type[1]	Depth (feet)	Dimensions (feet)	Method of lift[2]	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
296	0·2 mile W. of Mota Nagalpur.	..	Dg	41	9×7	..	Sandstone
297	1·5 miles NW. of Mota Nagalpur.	..	Dg	52	6×6	..	Coarse to medium sandstone.
298	0·8 mile NW. of Khedoi Nana.	Manji Jairam .	Dg	46	12×10	BM	Do.
299	0·9 mile NW. of Khedoi Mota.	Takhat Singh Pataji.	Dg	47	8×6	BM	Do.
300	1·1 miles NW. of Khedoi Mota.	Kuwarji Pancha	Dg	40	17×7	..	Do.
301	1 mile NW. of Khedoi Nana.	Kuwarji Pancha.	Dg, B	103	13×8	HC	Sandstone
302	0·85 mile NW. of Khedoi Nana.	Kuwar Jetha .	Dg	43	9×7	HC	Do.
303	0·9 mile NW. of Khedoi Nana.	Devraj Debia	Dg, B	139	8×5	BM	Do.
304	0·9 mile NW. of Khedoi Nana.	Abtar Ahmed .	Dg	45	10×6	..	Do.
305	0·8 mile NW. of Khedoi Nana.	Jareja Takhat Singh Bhupat Singh.	Dg	40	9×6	BM	Do.
306	1·0 mile NW. of Khedoi Nana.	Hasan Ahmad .	Dg	39	8×5	BM	Do.
307	0·95 mile NW. of Khedoi Nana.	Devraj Daya .	Dg	40	13×5	HC	Do.
308	Just South of Khedoi Nana.	Nawal Singh .	Dg	31	9×9	BM	Do.
309	0·6 mile NW. of Khedoi Nana.	Kuwarji Lowano	Dg	37	10×6	BM	Do.

See footnotes at end of table.

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)			3		
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj.	SS. slab, E. side	..	28·88	Aug. 12	D	85	Water has good taste. Curbed 0-12 ft.
Do.	SS. slab, W. side	1·0	44·86	Nov. 14	Un	..	Curbed 0-14 ft.
Do.	Lip of corner SS. slab, SW. side.	2·0	34·80	Nov. 17	I	82	Irrigation by 3 motes. Water has good taste.
Do.	Mid. SS. slab, E. side.	2·0	36·77	Do.	I	83	Irrigation by 2 motes. Water has good taste. Curbing 0-8 ft.
Do.	Mid. SS. slab, N. side.	2·0	35·30	Do.	I	82	Irrigation by one mote. Curbed 0-10 ft. Water has good taste.
Do.	Mid. Proj. SS. slab, N. side.	1·0	34·75	Do.	I	85	Irrigation by HO. Dug 43 ft. and one open boring 60 ft. deep. Curbed 0-10 ft. Water has good taste. Yield 140 gal./min.
Do.	Top of cemented wall, S. side.	2·0	31·12 (pumping level)	Do.	I	84	Irrigation by HO. Yields 58 gal./min. Curbed 0-14 ft. Water has good taste. Produces wheat, millet and vegetables.
Do.	Lip of Mid. slab, S. side.	2·5	28·80	Do.	I	84	Irrigation by 2 motes. Dug 39 ft. and then one open bore 100 ft. deep. Water has good taste. Produces wheat and vegetables.
Do.	Lip of proj. SS. slab, S. side.	1·0	30·95	Do.	Un	..	Curbed 0-3 ft.
Do.	Lip of proj. SS. slab, N. side.	2·5	27·94	Do.	I	84	Irrigation by 2 motes, working 8 hrs./day for 10 months/year. Curbed 0-10 ft. One boring in the well, depth not known.
Do.	Lip of SS. slab, N. Side.	2·0	28·05	Do.	I	82	Irrigation by 2 motes, working 10 hrs./day for 10 months a year. Curbed 0-8 ft. Water has good taste.
Do.	Corner SS. slab, S. side.	2·0	29·15 (pumping level)	Do.	I	84	Irrigation by HO, working 3 hrs./day for 10 months/year. Yields 170 gals. min. Water has good taste.
Do.	Mid. SS. slab, E. side.	2·0	16·82	Do.	I	80	Irrigation by 2 motes, working 8 hrs./day for 10 months/year. Curbed 0-9 ft. Water has slightly brackish taste.
Do.	Lip of mid. proj. SS. slab, N. side.	3·0	21.59	Nov. 18	I	82	Irrigation by 2 motes working 8 hrs./day for 10 months/year. Curbed 0-8 ft. Water has good taste.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
310	0·6 mile NW. of Khedoi Nana.	Narain Gabi .	Dg, B	36	13×8	..	Sandstone
311	Do	Radhika Das .	Dg	38	8×5	BM	Do.
312	0·65 mile NW. of Khedoi Nana.	Musa . .	Dg	34	13×12	BM	Do.
313	0·75 mile NW. of Khedoi Nana.	Budha (Ranmalji Hari Singhji)	Dg	35	14×10	BM	Do.
314	0·6 mile NW. of Khedoi Nana.	Narain Govindji	Dg	95	10×7	BM	Do.
315	0·42 mile NW. of Khedoi Nana.	Govind Jiwan .	Dg	36	8×10	BM	Do.
316	0·35 mile NW. of Khedoi Nana.	Haji Alimohammad.	Dg	32	10×7	BM	Do.
317	0·4 mile NW. of Khodoi Nana.	Govind Jiwan .	Dg	33	10×8	BM	Do.
318	0·48 mile NW. of Khedoi Nana.	Adam Galeria .	Dg	38	9×10	BM	Do.
319	0·5 mile NW. of Khedoi Nana.	Budha, Noor Mohammad.	Dg	42	9×15	BM	Do.
320	0·62 mile NW. of Khedoi Nana.	Do.	Dg	37	10×7	BM	Do,
321	0·65 mile NW. of Khodoi Nana.	Do.	Dg, B	37	10×8	BM	Do.

See footnotes at end of table.

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(D)	(P)
Upper Bhuj.	Lip of Mid. proj. SS. slab, SE. side.	1·0	21·70	Nov. 18	I	80	Irrigation by 3 motes, working 8 hrs./day for 10 months/year. Curbed 0-7 ft. Water has good taste.
Do.	Mid. proj. SS. slab, SW. side.	2·0	25·24	Do.	I	81	Irrigation by 2 motes, working 8 hrs./day for 10 months/year. Water has good taste.
Do.	Mid. proj. SS. slab, NE. side.	3·0	23·44	Do.	I	80	Irrigates 3 acres by 2 motes, working 8 hrs./day for 10 months a year. Water has good taste.
Do.	Lip of SS. slab, SE. side.	1·0	25·46	Do.	I	..	Irrigation by 2 motes, working 8 hrs./day for 10 months a year. Water has good taste.
Do.	Lip of SS. slab, S. side.	2·0	28·86	Do.	I	82	Irrigation by 2 motes, working 8 hrs./day for 10 months a year. Dug 32 ft. and then one open boring 63 ft. deep.
Do.	Lip of SS. slab, E. side.	3·0	30·12	Nov. 19	I	80	Irrigates 5 acres by 2 motes, working 8 hrs./day for 10 months/year. Curbing 0-11 ft.
Do.	SS. slab, S. side	2·0	17·97	Do.	I	74	Seasonal irrigation by one mote, working 8 hrs./day for 4 months/year. Produces millet after rains.
Do.	Lip of SS. slab, E. side.	1·0	20·07	Do.	I	74	Seasonal irrigation by 2 motes, working 8 hrs./day for 4 months/year. Curbing 0-9 ft.
Do.	Lip of mid. proj. SS. slab, S. side.	3·0	22·10	Do.	I	79	Irrigation by 3 motes, working 8 hrs./day for 10 months/year. Curbed 0-11 ft.
Do.	Lip of mid. proj. SS. slab, E. side.	3·0	20·36	Do.	I	82	Irrigation by 2 motes, Curbing 0-7 ft. Water has good taste.
Do.	Lip of mid. proj. SS. slab, S. side.	3·0	22·10	Do.	I	82	Irrigates 3 acres by one mote. Curbed 0-10 ft. Water has good taste.
Do.	Mid. SS. slab, E. side.	2·0	21·30	Do.	I	80	Irrigates 5 acres by 2 motes, working 8 hrs./day for 10 months a year. Dug 37 ft and then one boring 50 ft. deep. Water has good taste.

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type[1]	Depth (feet)	Dimensions (feet)	Method of lift[2]	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
322	1·1 miles NW. of Khedoi Mota.	Ayub Abraham	Dg	37	9×6	BM	Sandstone
323	1·2 miles NW. of Khedoi Mota.	Jagmal . .	Dg	35	11×7	BM	Do.
324	1·3 miles NW. of Khedoi Mota.	Bhoj Rajji Shesh malji.	Dg	32	12×12	BM	Do.
325	1·42 miles NW. of Khedoi Mota.	Ahmad Mohammad Suraya.	Dg	44	12×6	HO	Do.
326	1·45 miles NW. of Khedoi Mota.	Morarji Arjun	Dg	30	10×7	..	Do.
327	1·2 miles NW. of Khedoi Mota.	Narsi Lalji .	Dg	35	13×8	HO	Do.
328	1·25 miles NW. of Khedoi Mota.	Triku Daya .	Dg	35	12×9	BM	Do.
329	1·3 miles NW. of Khedoi Mota.	Bachu Bhimji	Dg, B	67	10×5	BM	Do.
330	0·5 mile NW. of Khedoi Mota.	Ali Mohammed	Dg	36	8×7	BM	Do.
331	Just North of Khedoi Nana.	Jiwan Gangji	Dg	36	8×6	BM	Do.
332	Do.	Abu Ahmed Galeria.	Dg	40	9×6	BM	Do.

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj.	Mid. SS. slab, E. side.	2·0	23·15	Nov. 19	I	80	Irrigation by 2 motes, working 8 hrs./day for 10 months/year. Curbed 0-8 ft.
Do.	Do.	3·0	22·26	Do.	I	83	Irrigates 3 acres by one mote, working 8 hrs./day for 10 months/year. Curbed 0-8 ft. Water has good taste.
Do.	Do.	3·0	23·75	Do.	I	82	Irrigation by one mote, working 8 hrs./day for 4 months/year. Curbed 0-9 ft. Water has good taste.
Do.	Do.	1·0	30·78	Do.	I	85	Irrigates 3 acres by HC, working 4 hrs./day for 8 months/year. Yielding 100 gals./min. Curbed 0-14 ft. Water has good taste.
Do.	Proj. SS. slab, E. side.	2·0	24·80	Do.	Un	74	Curbed 0-10 ft.
Do.	Mid. SS. slab, S. side.	2·0	24·49	Do.	I	83	Irrigation by HC, working 6 hrs./day for 8 months/year. Yielding 170 gals./min. Curbed 0-16 ft. Water has good taste.
Do.	Mid. SS. slab, W. side.	2·0	23·18	Do.	I	83	Irrigates 5 acres by 2 motes, working 8 hrs./day for 10 months/year. Curbing 0-17 ft.
Do.	Mid. SS. slab, NW. side.	3·0	26·20	Do.	I	82	Irrigates 3 acres by 2 motes, working 8 hrs./day for 10 months/year. Dug 37 ft. and then one boring 30 ft. deep.
Do.	Mid. SS. slab, W. side.	2·0	21·85	Nov. 20	I	83	Irrigation by one mote, working 8 hrs./day for 10 months/year. Curbed 0-12 ft. Water has slight brackish taste.
Do.	Mid. proj. SS. slab, W. side.	2·0	24·94	Do.	I	83	Irrigation by 2 motes, working 8 hrs./day for 10 months/year. Curbed 0-10 ft. Water has good taste.
Do.	Mid. proj. SS. slab, N. side.	1·0	27·66	Do.	I	82	Irrigation by one mote, working 8 hrs./day for 10 months/year. Curbed 0-14 ft. Water has slightly brackish taste. Step well.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type [1]	Depth (feet)	Dimensions (feet)	Method of lift [2]	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
333	Just North of Khedoi Nana.	Karmai Ratna	Dg	35	7×6	BM	Sandstone . .
334	0·3 mile N. of Khedoi Nana.	Takhat Singh .	Dg	37	13×8	BM	Do.
335	0·2 mile N. of Khedoi Nana.	Karamai Govind	Dg	36	13×9	BM	Do.
336	0·3 mile N. of Khedoi Nana.	Kesheoji Ratansi.	Dg, B	236	9×7	BM	Do.
337	Do.	Hirji Dhanji .	Dg	37	9×6	BM	Do.
338	0·4 mile N. of Khedoi Nana.	Raja Madan Patel.	Dg	42	13×7	BM	Do.
339	0·45 mile N. of Khedoi Nana.	Nanji Nara .	Dg	42	8×6	BM	Do.
340	0·2 mile NNE of Khedoi Nana.	Morarji Arjun Sutar.	Dg	31	12×6	BM	Do.
341	0·3 mile N. of Khedoi Nana.	Hardas Lalji Sutar.	Dg	39	16×16	BM	Do.
342	Do.	Shyamji Lalji	Dg	39	17×6	HC	Do.

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)	8		
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj.	Mid. proj. SS. slab, NE. side.	1·0	20·80	Nov. 20	I	..	Seasonal irrigation by one mote. Curbed 0-10 ft. Water has slight brackish taste.
Do.	Proj. SS. slab, NE. corner.	2·0	23·10	Do.	I	81	Irrigation by 2 motes, working 8 hrs./day for 10 months a year. Curbed 0-10 ft. Water has slight brackish taste.
Do.	Mid. proj. SS. slab, E. side.	2·0	22·35	Do.	I	83	Irrigates 3 acres by 2 motes, working 8 hrs./day for 10 months/year. Curbing 0-11 ft. Produces wheat and millet. Water has slightly brackish taste.
Do.	Mid. proj. SS. slab, E. side.	1·0	22·34	Do.	I	84	Irrigates 3 acres by 2 motes, working 8 hrs./day for 10 months/year. Dug 36 ft. and then one open boring 200 ft. deep. Water brackish.
Do.	Mid. proj. SS. slab, E. side.	2·0	24·04	Do.	I	82	Irrigates about 4 acres by 2 motes, working 8 hrs./day for 10 months/year. Curbed 0-13 ft. Water has good taste.
Do.	SS. slab, SE. corner.	2·0	27·57	Do.	I	80	Irrigates 4 acres by 2 motes, working 8 hrs./day for 10 months/year. Curbed 0-11 ft. Water is slightly brackish.
Do.	SS. slab, S. side	1·0	28·65	Do.	I	82	Irrigates 4 acres by 2 motes, working 8 hrs./day for 10 months/year. Curbed 0-12 ft. Water has good taste.
Do.	Mid. SS. slab, E. side.	3·0	19·58	Do.	I	76	Seasonal irrigation by 2 motes. Curbing 0-12 ft. Water is slightly brackish.
Do.	Mid. proj. SS. slab, E. side.	3·0	21·86	Do.	I	81	Irrigates 8 acres by 4 motes, working 8 hrs./day for 10 months/year. Curbed 0-20 ft. Water has slight brackish taste.
Do.	Mid. proj. SS. slab, W. side.	2·0	22·35	Do.	I	82	Irrigates about 5 acres by HC, working 8 hrs./day for 6 months/year. Curbing 0-11 ft. Yields 230 gals./min. Water has slight brackish taste.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
343	0·4 mile N. of Khedoi Nana.	Ramji Valji Parmar.	Dg	39	9×7	HC	Sandstone . .
344	0·45 mile N. of Khedoi Nana.	Dev Ram Ramji	Dg	40	8×8	BM	Do.
345	0·5 mile N. of Khedoi Nana.	Premji Jairam	Dg	43	11×6	HC	Do.
346	0·6 mile N. of Khedoi Nana.	Jafer Abdullah	Dg	40	12×5	BM	Do.
347	Do.	Ladhu Kheta .	Dg	41	9×7	BM	Do.
348	0·55 mile N. of Khedoi Nana.	Kuwarji .	Dg	38	11×10	HC	Do.
349	0·7 mile N. of Khedoi Nana.	Narshi Lalji .	Dg	42	9×6	BM	Do
350	Do.	Jeju Hardas .	Dg	38	19×7	BM	Do.
351	0·25 mile W. of Khedoi Mota.	Ramji Valji .	Dg	25	7×7	..	Do.
352	0·1 mile N. of Khedoi Mota.	Village well .	Dg	23	7×5	..	Do.
353	Do.	Do.	Dg	23	8×6	..	Do.
354	Do.	Do.	Dg	16	5×5	..	Do.
355	0·4 mile N. of Khedoi Mota.	Umed Singh Narsing.	Dg	27	9×7	BM	Do.

See foot notes at end of table.

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj.	Mid. proj. SS. slab, E. side.	2·0	22·06	Nov. 20	I	84	Irrigates 3 acres by HO, working 10 hrs./day for 8 months/year. Curbed 0-11 ft. Water has slightly brackish taste.
Do.	Do.	2·0	25·20	Do.	I	81	Irrigates 3 acres by 2 motes, working 8 hrs./day for 10 months/year. Curbed 0-15 ft. Water has good taste.
Do.	Mid. proj. SS. slab, S. side.	2·0	28·65	Do.	I	83	Irrigates 4 acres, working 6 hrs./day for 8 months/year. Yield 120 gals./min. Curbing 0-17 ft. Water has good taste.
Do.	Mid. proj. SS. slab, E. side.	2·0	26·76	Nov. 21	I	80	Irrigate 2 acres by 2 motes, working 8 hrs./day for 10 months a year. Curbing 0-9 ft. Water has good taste.
Do.	Mid. proj. SS. slab, S. side.	2·0	29·17	Do.	I	84	Irrigation by one mote for 10 hrs./day and 10 months/year. Water has good taste. Curbed 0-12 ft.
Do.	Mid. proj. SS. slab, E. side.	2·0	23·19	Do.	I	85	Irrigates 3 acres, working 6 hrs./day for 8 months/year. Water suitable for all cultivation purposes.
Do.	Do.	3·0	29·80	Do.	I	85	Irrigates 3 acres by one mote. Curbed 0-11 ft. Water has good taste.
Do.	Do.	2·0	22·84	Do.	I	85	Irrigates 4 acres by 2 motes, working 10 hrs./day for 10 months/year. Water has good taste.
Do.	Mid. proj. SS. slab, N. side.	5·0	19·92	Nov. 23	D	..	Curbed 0-24 ft.
Do.	Top of curbing, E. side.	5·0	13·58	Do.	Un	..	Curbed 0-7 ft.
Do.	Do.	5·0	9·58	Do.	D	..	Curbed 0-3 ft.
Do.	Do.	5·0	6·21	Do.	D	..	Do.
Do.	Mid. proj. SS. slab, S. side.	2·0	15·92	Do.	I	..	Irrigates 4 acres by 3 motes, working 8 hrs./day for 10 months/year. Curbed 0-4 ft. Water has good taste.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
356	0·3 mile N. of Khedoi Mota.	Halubha Vaji Singh.	Dg	35	8×6	BM	Sandstone . .
357	Do.	Gulab Chand Bhagwanji	Dg	34	10×7	BM	Do.
358	0·32 mile N. of Khedoi Mota.	Jivaram Dana .	Dg	37	10×6	BM	Do.
359	0·35 mile N. of Khedoi Mota.	Bhuraji . .	Dg	31	9×7	BM	Do.
360	0·38 mile N. of Khedoi Mota.	Devraj Daya .	Dg	37	9×8	BM	Do.
361	0·4 mile N. of Khedoi Mota.	Narsi Lalji .	Dg	37	10×7	BM	Do.
362	Do.	Do.	Dg	37	10×7	BM	Do.
363	0·45 mile NNE of Khedoi Mota.	Dhanji Lalji .	Dg	39	15×12	BM	Do.
364	0·5 mile N. of Khedoi Mota.	Golal Chand Bhagwanji.	Dg	39	9×7	BM	Do.
365	0·2 mile N. of Khedoi Mota.	Triku Daya .	Dg	21	9×7	..	Do.
366	Do.	Narsi Lalji .	Dg	37	13×6	..	Do
367	0·4 mile NNE of Khedoi Mota.	Dharmada Mavji Akhai.	Dg	24	9×5	..	Do.

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch —*contd.*

Geologic horizon	Water Level				Use 8	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj.	Mid. proj. SS. slab, S. side.	2·0	16·92	Nov. 23	I	..	Irrigates 4 acres by 2 motes, working 8 hrs./day for 10 months/year. Water has good taste.
Do.	Do.	2·0	16·70	Do.	I	..	Irrigates 3 acres by 2 motes, working 8 hrs./day for 10 months/year. Water has good taste.
Do.	Do.	3·0	19·0	Do.	I	..	Irrigates 3 acres by 2 motes, working 10 hrs./day for 10 months/year. Water has good taste.
Do.	Do.	2·0	17·02	Do.	I	..	Irrigates 2 acres by 2 motes, working 10 hrs./day for 10 months/year. Water has good taste.
Do.	Do.	2·0	21·00	Do.	I	..	Irrigates 8 acres by 2 motes, working 10 hrs./day for 10 months/year. Water has good taste.
Do.	Mid. SS. slab, E. side.	2·0	25·52	Do.	I	..	Irrigates 3 acres by 2 motes, working 10 hrs./day for 10 months/year. Curbing 0-13 ft. Water has good taste. Produces wheat and vegetables.
Do.	Mid. proj. SS. slab, S. side.	2·0	22·79	Do.	I	..	Irrigates 4 acres by 2 motes, working 10 hrs./day for 10 months/year. Curbing 0-10 ft. Water has good taste. Cultivates wheat and vegetables.
Do.	Mid. proj. SS. slab, E. side.	2·0	21·80	Nov. 24	I	..	Irrigates 3 acres by 2 motes, working 10 hrs./day for 10 months/year. Curbing 0-13 ft. Water has good taste. Cultivates wheat and vegetables.
Do.	Mid. proj. SS. slab, N. side.	2·0	26·00	Do.	I	..	Irrigates 7 acres by 2 motes, working 10 hrs./day for 10 months/year. Curbed 0-11 ft. Water has good taste. Irrigates wheat and vegetables.
Do.	Mid. proj. SS. slab, E. side.	2·0	16·24	Do.	Un	..	Curbed 0-9 ft.
Do.	Mid. proj. SS. slab, S. side.	..	19·07	Do.	Un	..	Do.
Do.	Mid. proj. SS. slab, N. side.	..	16·82	Nov. 25	Un	..	Curbed 0-9 ft. Water has saline taste.

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
368	0·5 mile NE of Khedoi Mota.	Harji Gangadas Mistry.	Dg	36	12×11	BM	Sandstone
369	Do.	Madhubha Hadamatji.	Dg	38	12×7	BM	Do.
370	Do.	Jeram Ramji .	Dg	33	13×7	HC	Do.
371	0·55 mile NE of Khedoi Mota.	Kera Sanagan .	Dg	33	9×7	BM	Do.
372	0·65 mile NE of Khedoi Mota.	Madhavji Mandan.	Dg	34	13×7	BM	Do.
373	Do.	Sutar Karamsi Hardas.	Dg	45	12×7	BM	Do.
374	0·7 mile NE of Khedoi Mota.	Shiva Lal Kalidas.	Dg	45	9×7	BM	Do.
375	0·65 mile NE of Khedoi Mota.	Jafar . .	Dg	50	..	BM	Do.
376	0·65 mile E. of Khedoi Mota.	Ramji Lalji .	Dg	50	8×6	BM	Do.
377	0·6 mile E. of Khedoi Mota.	Do.	Dg	44	9×6	BM	Do.
378	Do.	Do.	Dg	51	8×6	BM	Do.
379	0·7 mile E. of Khedoi Mota.	Do.	Dg	42	..	..	Do.
380	0·65 mile E. of Khedoi Mota.	Bhojraj Seahmalji.	Dg	37	9×5	..	Do.
381	0·75 mile E. of Khedoi Mota.	Jivaram . .	Dg	47	10×7	BM	Do.
382	0·9 mile E. of Khedoi Mota.	Raja Devji .	Dg	50	9×7	BM	Do.
383	0·45 mile E. of Khedoi Mota.	Valji Pursottam	Dg	40	9×6	BM	Do.

See footnotes at end of table.

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj.	Mid. proj. SS. slab, E. side.	..	20·95	Nov. 25	I	..	Irrigates 13 acres by 4 motes. Curbed 0-10 ft. Water has good taste.
Do.	Mid. proj. SS. slab, E. side.	2·0	23·34	Do.	I	..	Irrigates 4 acres by motes. Curbed 0-8 ft. Water has good taste.
Do.	Mid. proj. SS. slab, E. side.	2·0	33·68	Do.	I	..	Irrigates 4 acres by H.C, working 6 hrs./day for 8 months/year. Yields 170 gal./min.
Do.	Mid. SS. slab, S. side.	..	22·74	Do.	I	..	Irrigates 2 acres by 2 motes. Curbed 0-10 ft.
Do.	Proj. SS. slab, N. side.	2·0	26·45	Do.	I	..	Irrigates 4 acres by motes. Curbed 0-13 ft. Water has good taste.
Do.	Proj. SS. slab, S. side.	2·0	26·50	Do.	I	..	Irrigates 7 acres by 3 motes. Curbed 0-16 ft. Water has good taste. Irrigates wheat and vegetables.
Do.	Mid. proj. SS slab, S. side.	2·0	33·73	Do.	I	..	Irrigates one acre by 2 motes. Cultivates wheat and vegetables. Curbing 0-7 ft.
Do.	Do. . .	2·0	33·72	Do.	I	..	Irrigates 2 acres by 2 motes. Cultivates wheat and vegetables. Curbing 0-16 ft. Water has good taste.
Do.	Mid. SS. slab, S. side.'	2·0	27·16	Nov. 26	I	..	Seasonal irrigation by 2 motes. Curbing 0-10 ft. Water has brackish taste.
Do.	Mid. proj. SS. slab, S. side.	..	25·30	Do.	I	..	Seasonal irrigation by 2 motes. Water has brackish taste.
Do.	Mid. proj. SS. slab, W. side.	..	24·24	Do.	I	..	Seasonal irrigation by 2 motes. Curbing 0-8 ft. Water is brackish.
Do.	Do. . .	..	25·90	Do.	Un	..	Curbing 0·8 ft.
Do.	Mid. SS. slab, N. side.	..	25·72	Do.	Un	..	Curbing 0-14 ft. Water has brackish taste.
Do.	Do. N. side.	..	29·47	Do.	I	..	Seasonal irrigation of 5 acres by 2 motes. Water has good taste.
Do.	Mid. proj. SS. slab, W. side.	..	43·72	Do.	I	..	Irrigates 2 acres by 2 motes. Cultivates wheat and vegetables. Curbed 0-16 ft.
Do.	Do. . .	2·0	20·02	Do.	I	..	Seasonal irrigation by 2 motes. Curbed 0-9 ft. Water has brackish taste.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type [1]	Depth (feet)	Dimensions (feet)	Method of lift [2]	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
384	0·65 mile N. of Khedoi Mota.	Karams Hardas	Dg	43	13×12	HC	Sandstone . .
385	0·55 mile N. of Khedoi Mota.	Girdhar Monsi .	Dg	39	15×9	BM	Do.
386	Do.	Raghu Ramji .	Dg	39	9×7	BM	Do.
387	0·6 mile N. of Khedoi Mota.	Shivubha Meghaji.	Dg	43	12×7	BM	Do.
388	0·75 mile N. of Khedoi Mota.	Do. . .	Dg	45	8×6	BM	Do.
389	0·75 mile NE of Khedoi Mota.	Jafar Abdullah	Dg	43	12×7	BM	Do.
390	Do.	Chaturji Lalji .	Dg	35	13×8	..	Do.
391	0·8 mile NE of Khedoi Mota.	Chaturji Ladhaji.	Dg	48	12×8	BM	Do.
392	Do.	Mandan Mistry	Dg	27	11×7	BM	Do.
393	Do.	Ramji Lalji .	Dg	43	11×6	BM	Do.
394	Do.	Do. . .	Dg	34	10×11	..	Do.
395	0·9 mile NE of Khedoi Mota.	Lokaj Hanuji .	Dg	44	13×6	HC	Do.
396	Do.	Govanal Juvan	Dg	47	17×9	HC	Do.
397	0·5 mile NE of Khedoi Mota.	Govamal Manji	Dg	46	12×7	..	Do.
398	0·7 mile E of Khedoi Mota.	Megh ji Kalayan Singh.	Dg	55	10×6	..	Do.
399	1·15 miles E. of Khedoi Mota.	Hirji Dhanji	Dg	58	14×5	HC	Do.

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj.	Mid. proj. SS. slab, E. side.	..	22·93	Nov. 26	I	..	Irrigates 7 acres by H. O. Yields 170 gals./min. Water has good taste, cultivates wheat, vegetables, etc. Curbing 0-10 ft.
Do.	Mid. proj. SS. slab, S. side.	..	30·55	Do.	I	..	Irrigates 7 acres by 2 motes. Curbed 0-12 ft. Cultivates wheat and vegetables.
Do.	Projecting W. side.	2·0	27·46	Do.	I	..	Irrigates 3 acres by 2 motes. Curbing 0-9 ft. Cultivates wheat and vegetables.
Do.	Mid. SS. slab, E. side.	2·0	25·60	Nov. 27	I	..	Irrigation by 2 motes. Curbed 0-8 ft. Water has good taste.
Do.	Do. . .	2·0	26·02	Do.	I	..	Irrigates 4 acres by 2 motes. Cultivates fruits and vegetables.
Do.	Mid. proj. SS. slab, S. side.	2·0	24·60	Nov. 28	I	..	Garden irrigation by 3 motes. Curbing 0-9 ft. Water has good taste.
Do.	Mid. proj. SS. slab, E. side.	..	21·70	Do.	Un	..	Curbing 0-16 ft. Water has brackish taste.
Do.	Do. . .	2·0	25·80	Do.	I	..	Irrigates acres by 3 motes. Curbed 0-8 ft.
Do.	SS. slab, N. side	3·0	26·95	Do.	I	..	Irrigates acres, by 2 motes. Water has good taste. Curbed 0-10 ft.
Do.	Mid. proj. SS. slab, S. side.	2·0	27·78	Do.	I	..	Irrigates acres, by 2 motes. Water has good taste. Curbed 0-15 ft.
Do.	Do. . .	..	22·45	Do.	Un	..	Water has brackish taste. Curbing 0-8 ft.
Do.	Do. . .	..	36·85	Do.	I	.	Irrigates 14 acres by H. C. Yielding 170 glas./min. Curbing 0-11 ft.
Do.	Do. . .	2·0	36·35	Do.	I	..	Irrigates 10 acres by H. O. Yields 170 gals. ./min. Curbed 0-15 ft. Water has good taste.
Do.	Mid. proj. SS. slab, S. side.	2·0	28·9	Do.	Un	..	Curbed 0-12 ft. Water has brackish taste.
Do.	Do. . .	2·0	38·6	Nov. 30	Un	..	Curbed 0-13 ft. Water has brackish taste.
Do.	Do. . .	2·0	43·00	Do.	I	..	Irrigates 5 acres by H. O. Yields 150 gals./min. Curbed 0-18 ft. Irrigates wheat, etc.

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
400	1·1 miles ENE of Khedoi Mota.	Bhanji Muraji .	Dg	51	13×12	..	Sandstone . .
401	1·0 mile E. of Khedoi Mota.	Haraji Ganga Singh.	Dg	51	10×6	BM	Do.
402	1·0 mile ENE of Khedoi Mota.	Jaiji Gangdas .	Dg	57	12×6	HO	Do.
403	Do. . .	Do. . .	Dg	57	12×6	HO	Do.
404	0·9 mile NE of Khedoi Mota.	Meghji Vira .	Dg	46	10×9	HO	Do.
405	0·9 mile E. of Khedoi Mota.	Meghaji Vira .	Dg	42	9×7	..	Do.
406	0·25 mile SWS of Loharia.	Manji Jairam Jagmal Jairam.	Dg, B	143	17×7	BM	Do.
407	0·15 mile SW. of Loharia.	Meghji Karsan	Dg	56	8×5	BM	Do.
408	0·15 mile S. of Loharia.	Premji Bhima .	Dg	66	19×6	BM	Do.
409	0·05 mile W. of Loharia.	Vira Devram .	Dg	39	8×6	..	Yellowish brown Sandstone.
410	0·1 mile NW. of Loharia.	Ibrahim Ismail .	Dg	50	11×5	BM	Sandstone . .
411	NW. corner of Loharia.	Fatta Juma .		46	8×5	BM	Do.
412	0·2 mile N. of Loharia.	Jina Musa .	Dg	52	8×5	BM	Do.
413	0·3 mile NNW of Loharia.	Devji Jairam .	Dg	43	10×6	BM	Do.
414	0·3 mile NWN of Loharia.	Petha Devan Das	Dg	51	9×6	BM	Do.
415	0·3 mile N. of Loharia.	Juma Noor Mohammad.	Dg	42	13×4	BM	Do.

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 8	Temperature (F°)	Remarks
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj.	Mid. proj. SS. Slab, S. side	..	34·88	Nov. 30	Un	..	Curbing 0-16 ft.
Do.	Do. . .	..	39·65	Do.	I	..	Irrigates 7 acres by 2 motes. Curbed 0-13 ft. Cultivates wheat and vegetables.
Do.	Do. . .	2·0	43·62	Do.	I	..	Irrigates 7 acres by H.C Yields 110 gals./min. Water has good taste. Curbing 0-16 ft.
Do.	Do. . .	2·0	43·62	Do.	I	..	Irrigates 7 acres by H.C. Yields 110 gals./min. Curbed 0-16 ft.
Do.	Do. . .	2·0	32·00	Do.	I	..	Irrigates 7 acres by H.O. Yields 170 gals./min. Curbed 0-14 ft.
Do.	Do. . .	2·0	31·90	Do.	Un	..	Curbed 0-11 ft.
Do.	Mid. SS. slab, S. side.	1·0	51·48	Dec. 1	I		Irrigates 7 acres by 2 motes. Dug 63 ft. then two open bores one 80 ft. and another 50 ft. deep. Water has good taste.
Do.	Mid. SS. slab, E. side.	2·0	41·18	Do.	I	81	Irrigates 2 acres by one mote. Curbing 0-7 ft. Water has good taste.
Do.	Mid. SS. slab. N. side.	1·0	43·90	Do.	I	80	Irrigates 2 acres by 2 motes, working 8 hrs. day for 10 months/year Water has good taste. Curbing 0-16 ft.
Do.	Mid. proj. SS. slab, W. side.	1·0	34·66	Do.	Un	..	Curbing 0-6 ft. Contains dirty water.
Do.	Mid. proj. SS. slab, N. side.	2·0	37·66	Do.	I	81	Irrigates 2 acres by 3 motes, working 8 hrs./ day for 10 months a year Water has good taste.
Do.	Mid. SS. side, E. side.	1·0	36·22	Do.	I	81	Irrigation by one mote, working 8 hrs./day for 10 months a year Curbing 0-6 ft.
Do.	Mid. SS. slab, W. side.	2·0	33·98 (pumping level)	Do.	I	83	Irrigation by one mote. Water has good taste. Curbing 0-4 ft.
Do.	Mid. SS. slab, B. side.	1·0	32·03	Do.	I	..	Seasonal irrigation by one mote. Water has slightly brackish taste.
Do.	Do. . .	1·0	32·02	Do.	I	..	Seasonal irrigation by 2 motes. Curbing 0-5 ft. Water has good taste.
Do.	Do. . .	2·0	32·43	Do.	I	81	Irrigates 3 acres by one mote, working 8 hrs. day for 10 months/year. Water has good taste.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
416	0·2 mile NE. of Loharia.	Noor Mohammad.	Dg	30	5×6	BM	Sandstone . .
417	SE. corner of Loharia.	Kuwarji Pancha	Dg, B	101	14×5	BM	Do.
418	0·1 mile SE. of Loharia.	Manji Shiva .	Dg	48	6×5	BM	Do.
419	0·1 mile E. of Loharia.	Bachu Puja .	Dg	46	9×5	BM	Do.
420	0·4 mile W. of Loharia.		Dg	44	6×8	..	Do.
421	0·3 mile W. of Loharia.		Dg	88	6×6	..	Do.
422	0·2 mile NW. of Loharia.		Dg	42	9×6	..	Do.
423	NE. corner of Loharia.	Kuwarji Pancha	Dg,B	180	10×7	BM	Do.
424	0·4 mile SW. of Wada.	Osman Duda .	Dg	43	8×6	BM	Sandstones and Shales.
425	0·1 mile S. of Wada.	Ali Mamu .	Dg	24	11×14	BM	Do.
426	0·5 mile NW. of Wada.		Dg	34	9×6	..	Do.
427	0·55 mile N. of Wada.	Umar Megha .	Dg	31	15×5	BM	Sandstone, argillaceous.
428	0·3 mile E. of Wada.	Mamu Kana .	Dg	23	12×5	BM	Do.
429	0·9 mile NE. of Mathada.	Poba Harbam .	Dg	39	9	BM	Coarse-grained white sandstone.
430	0·4 mile S. of Pantia.	Gang Das Premji	Dg	58	15×8	BM	Do.

See footnotes at end of table.

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj.	Mid. proj. SS. slab, S. side.	1·0	31·13	Dec. 1	I	..	Seasonal irrigation by one mote. Water has good taste. Curbing 0-3 ft.
Do.	Mid. proj. SS. slab, W. side.	2·0	34·20 (pumping).	Do.	I	..	Irrigates 7 acres by 3 motes. Dug. 51 ft. and then one boring 50 ft. deep. Water has good taste.
Do.	Mid. SS. slab, E. side.	2·0	31·03	Do.	I	..	Seasonal irrigation by one mote. Water has good taste.
Do.	Do.	3·0	32·10	Do.	I	83	Irrigation by one mote working 8 hrs./day for 10 months/year. Curbing 0-9 ft. Water has good taste.
Do.	Do	1·0	30·60	Do.	Un	80	Curbed 0-12 ft. Water has good taste.
Do.	Do.	1·0	31·73	Do.	Un	..	Curbed 0-6 ft. Water has good taste.
Do.	Do.	1·0	32·85	Do.	Un	..	Curbed 0-3 ft. Water turbid and smelling but has good taste.
Do.	Mid. proj. SS. slab, E. side.	1·0	32·2	Do.	I	84	Irrigation by 2 motes, Dug 50 ft. and then one open bore 80 ft. deep.
Lower Bhuj.	Do.	2·0	25·67	Dec. 2	I	81	Irrigates 3 acres by 2 motes, working 8 hrs./day for 10 months/year. Water has good taste.
Do.	Mid. proj. SS. slab, N. side.	3·0	15·65	Do.	I	82	Irrigates 1½ acres by 2 motes. Water has good taste. Curbing 0-8 ft.
Do.	Mid. proj. SS. slab, E. side.	1·0	31·63	Do.	Un	..	Curbing 0-12 ft.
Do.	Mid. proj. SS. slab, N. side.	2·0	22·07	Do.	I	85	Irrigates 2 acres by 2 motes, working 8 hrs/day for 10 months/ year. Curbing 0-8 ft. water has good taste.
Do.	Top of SS. slab	3·0	19·00	Do.	I	84	Irrigates 2 acres by one mote. Water has good taste. Curbing 0-8 ft.
Upper Bhuj.	Mid. proj. SS. slab.	0	34·35	Do.	I	84	Irrigation by 2 motes. Curbing 0-15 ft. Water has good taste.
Do.	Mid. SS. slab E. side.	2·0	32·09	Dec. 3	I	81	Irrigates 7 acres by 2 motes, working 8 hrs. day for 10 months/yea Curbing 0-6 ft.

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
431	0·6 mile S. of Pantia.	Devji Kanji .	Dg	41	9×6	BM	Coarse-grained white sandstone.
432	0·5 mile S. of Pantia.	Premji Kanji .	Dg	52	9×7	HC	Do.
433	0·5 mile ESE of Pentia.	Govind Kanji .	Dg	49	9×7	BM	Do.
434	0·25 mile NE of Puntia.	Devji Kanji .	Dg	50	15×6	BM	Do.
435	0·2 mile N.E. of Pantia.	Premji Kanji .	Dg, B	130	6×12	BM	Do.
436	0·1 mile E. of Pantia.	Govind Kanji .	Dg, B	110	9×6	BM	Do.
437	0·2 mile E. of Pantia.	Kanji Banji .	Dg	59	9×6	BM	Do.
438	0·2 mile S. of Pantia.	Dhan Das Premji.	Dg	59	10×6	BM	Sandstone . .
439	0·15 mile S. of Pantia.	Kanji Premji .	Dg, B	170	10×6	BM	Do.
440	0·15 mile SE of Pantia.	Devji Premji .	Dg, B	122	10×6	BM	Do.
441	0·1 mile S. of Pantia.	Kanji Premji .	Dg, B	188	9×6	BM	Do.
442	Just South of Pantia	Devsi Kanji .	Dg, B	126	9×11	BM	Do.

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use [3]	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj.	Mid. proj. SS. slab, E. side.	2·0	38·60	Dec. 3	I	81	Irrigates 5 acres by 2 motes. Water has good taste. Curbing 0-8 ft.
Do	Mid. SS. slab, E. side.	1·0	45·20 (pumping).	Do.	I	84	Irrigates 8 acres by H.O. working 9 hrs./day for 10 months a year. Water has good taste. Curbing 0-5 ft.
Do.	Do.	2·0	38·93	Do.	I	83	Irrigates 7 acres by 2 motes, working 8 hrs./day for 10 months/year. Water has good taste.
Do.	Do.	2·0	38·42	Do.	I	79	Irrigation by one mote. Water has brackish taste. Curbing 0-6 ft. Seasonal use.
Do.	Do.	3·0	41·00	Do.	I	..	Irrigates 3 acres by 2 motes. Dug 50 ft. then two open bores one 60 ft. and the other 80 ft. deep. Water brackish.
Do.	Mid SS. slab	1·0	44·14	Do.	I	82	Irrigates 8 acres by 2 motes. Water has good taste. Curbing 0-6 ft.
Do.	Mid. SS. slab, E. side.	1·0	51·88 (pumping).	Do.	I	81	Irrigation by 2 motes. Water has good taste. Curbing 0-6 ft.
Do.	Mid. proj. SS. slab, E. side.	3·0	47·01	Do.	I	84	Irrigates 8 acres by 2 motes. Curbing 0-6 ft. Water has slightly brackish taste.
Do.	Mid. SS. slab, E. side.	2·0	43·23	Do.	I	80	Irrigates 3 acres by 2 motes. Dug 60 ft. and then one open boring 110 ft. deep. Water has slight brackish taste.
Do.	Do.	2·0	48·40	Do.	I	81	Irrigation by one mote. Dug 52 ft. and then one open boring 70 ft. deep. Water has good taste.
Do.	Mid. proj. SS. slab E. side.	2·0	58·30	Do.	I	84	Irrigates 2 acres by 2 motes. Dug 63 ft and then one open boring 75 ft. deep. Curbing 0-23 ft. Water slightly brackish.
Do.	Do.	2·0	52·70	Do.	I	84	Irrigation by 2 motes. Dug 76 ft. and then open boring 50 ft. deep. Curbing 0-5 ft. Water has good taste.

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type[1]	Depth (feet)	Dimensions (feet)	Method of lift[2]	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
443	0·05 mile E. of Pantia.	Devji Premji .	Dg, B	247	12×6	BM	Sandstone . .
444	Just North of Pantia.	Akchal Garg Das	Dg	68	9×6	BM	Do.
445	0·15 mile S. of Pantia.	Laddha Teja .	Dg, B	214	9×6	BM	Do.
446	0·2 mile SW. of Pantia.	Nanji Kanji .	Dg, B	239	13×6	HC	Do.
447	Do.	Akchal Gang Das	Dg, B	139	10×6	BM	Do.
448	0·05 mile SW. of Pantia.	Do.	Dg	55	9×7	BM	Do.
449	1·0 mile SW. of Pantia.	Yadawli . .	Dg	40	5×11	BM	Do.
450	0·8 mile SES. of Mota Nagalpur.	Aurji . .	Dg	30	13×8	BM	Do.
451	1·1 mile SE. of Mota Nagalpur.	Gunga Kasu .	Dg	23	..	BM	Cream coloured sandstone.
452	1·2 mile SE. of Mota Nagalpur.	Hasim Noor-Mohammad.	Dg	18	..	BM	Light brown coarse sandstone.
453	1·0 mile SE. of Mota Nagalpur.	Gunga Kasu .	Dg	30	..	BM	Sandstone . .
454	0·25 mile NNE of Sidungra.	Kishan Jetha .	Dg	44	21×11	HC	Do. .
455	0·25 mile N. of Sidungra.	Devraj Daya .	Dg	53	8×6	BM	Do.

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj.	Mid proj. SS. slab, E. side.	2·0	56·80	Dec. 3	I	..	Irrigation by 2 motes. Dug 67 ft. and then two open borings one 180 ft. and the other 150 ft. deep. Water has good taste.
Do.	Do. . .	2·0	43·40	Do.	I	83	Irrigates 3 acres by 2 motes. Curbing 0-11 ft. Water has good taste.
Do.	Mid. SS. slab, E. side.	2·0	45·85	Do.	I	82	Irrigates 7 acres by one mote. Dug 54 ft. and then one open bore 160 ft. deep. Water has brackish taste.
Do.	NE. corner SS. slab.	3.0	50·80 (pumping).	Dec. 4	I	83	Irrigation by HC. Yields 110 gals./min. Curbed 0-12 ft. Water has good taste.
Do.	Mid. SS. slab, E. side	2·0	43·29	Do.	I	81	Irrigates 5 acres by 2 motes. Dug 59 ft. and then one open bore 80 ft. deep. Water has good taste.
Do.	Do. . .	2·0	38·67	Do.	I	82	Irrigation by 2 motes. Curbed 0-4 ft. Water has very good taste.
Do.	Do. . .	2·0	31·65	Do.	I	82	Irrigates 3 acres by one mote. Curbed 0-7 ft. Water has good taste.
Do.	Do. . .	4·0	19·94	Nov. 23	I	83	Irrigates 3 acres by 3 motes. Curbing 0-17 ft. Water has good taste.
Do.	Mid. proj. SS. slab, W. side.	3·0	14·00	Do.	I	..	Irrigates 3 acres by 2 motes, working 10 hrs./day for 10 months/year. Curbing not uniform. Water has good taste.
Do.	Mid. SS. slab, E. side.	3·0	14·14	Do.	I	85	Irrigates one acre by one mote, working 10 hrs./day for 10 months/year. Water has good taste.
Do.	Do. .	3·0	19·16	Do.	I	86	Irrigates one acre by 2 motes, working 10 hrs./day for 10 months/year. Water has good taste.
Do.	Do. . .	2·0	29·58	Do.	I	..	Irrigates 3 acres by H.C. working 8 hrs. day for 4 months/year. Curbing 0-12 ft. Water has good taste.
Do.	Do. . .	3·0	32·68	Do.	1	80	Irrigates 2 acres by one mote, working 10 hrs./day for 10 months/year. Curbing 0-15 ft. Water has brackish taste.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
456	0·5 mile N. of Sidungra.	Japu Vishram .	Dg	50	11×8	BM	Sandstone .
457	0·6 mile N. of Sidungra.	Do. . .	Dg	47	11×8	BM	Do. . . .
458	2·0 miles N. of Tuna.	.	Dg	36	8×5	BM	Compact fossiliferous sandstones.
459	0·75 mile N. of Tuna.	Raja Jetha .	Dg	39	9×6	BM	Compact fine to medium grained sandstone.
460	0·8 mile N. of Khedoi Mota.	Ishwarji . .	Dg	40	8×5	BM	Sandstone . .
461	0·75 mile N. of Khedoi Mota.	..	Dg	42	9×7	MB	Do. . . .
462	0·8 mile N. of Khedoi Mota.	Jakuba Mohar Singh.	Dg	50	11×6	BM	Do. . . .
463	0·8 mile N. of Kheodi Mota.	Raghu Bhai Rup singh.	Dg	44	10×6	BM	Do. . . .
464	0·8 mile NE. of Kheodi Mota.	Mohammad Dadu.	Dg	25	9×8	BM	Do. . . .
465	0·1 mile W. of Bhuyad.	Musa Yakub .	Dg	43	14×7	BM	Vesicular Trap .
466	0·75 mile N. of Khedoi Mota.	Harji . .	Dg	39	8×5	BM	Sandstone . .
467	0·9 mile NEN of Khedoi Mota.	Devji Karsan .	Dg	47	10×6	BM	Do. . . .
468	0·8 mile NE. of Khedoi Mota.	Thakar . .	Dg	39	11×5	BM	Do. . . .
469	0·7 mile N. of Khedoi Mota.	Laddha Kanji .	Dg	42	12×9	BM	Do. . . .
470	0·6 mile N. of Khedoi Mota.	Madhavji Menon	Dg	36	9×5	BM	Do. . . .

See footnotes at end of table.

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj.	Mid. proj. SS. slab, E. side.	3·0	36·74	Nov. 28	I	82	Irrigates 3 acres by 2 motes, working 8 hrs./day for 10 months/year. Curbing 0-20 ft. Water has good taste.
Do.	Mid. SS. slab, E. side.	1·0	36·37	Do.	I	85	Irrigation by 2 motes Curbing 0-16 ft. Water has good taste.
Manchhar	Mid. proj. SS. slab, E. side.	..	26·37	Do.	I	80	Irrigation by one mote. Curbing 0-3 ft. Water has good taste.
Do.	Do. . .	2·0	27·89	Do.	I	85	Irrigation by 2 motes, working 8 hrs./day for 6 months/year.
Upper Bhuj.	Mid. proj. SS. slab, W. side.	3·0	28·39	Dec. 4	I	85	Irrigates 2 acres by one mote. Water has good taste. Curbing 0-8 ft.
Do.	Mid. proj. SS. slab, E. side.	3·0	24·11	Do.	I	83	Irrigation by 2 motes. Water has very good taste. Curbing 0-7 ft.
Do.	Mid. proj. SS. slab, S. side.	3·0	39·90	Do.	I	..	Irrigation by 2 motes. Water has good taste. Curbing 0-7 ft.
Do.	Do. . .	3·0	30·20	Do.	I	84	Irrigates 3 acres by 2 motes. Water has very good taste. Curbing 0-7 ft.
Do.	SS. slab, SE. corner.	2·0	17·96	Dec. 5	I	83	Irrigates 4 acres by one mote. Water has good taste. Curbing 0-11 ft.
Deccan	Proj. SS. slab, SW. side.	3·0	40·40	Do.	I	83	Irrigates about 3 acres by one mote. Curbing 0-4 ft. Water has good taste.
Upper Bhuj.	Mid. proj. SS. slab, S. side.	3·0	23·85	Do.	I	80	Irrigation by 2 motes. Water has good taste. Curbing 0-4 ft.
Do.	Low wall, N. side	3·0	34·30	Do.	I	83	Irrigates 5 acres by 3 motes. Water has good taste. Curbing 0-11 ft.
Do.	Mid. proj. SS. slab, E. side.	3·0	25·50	Do.	I	83	Irrigates 3 acres by 2 motes. Water has good taste. Curbing 0-10 ft.
Do.	Do. . .	3·0	25·19	Do.	I	80	Irrigates about 3 acres by one mote. Water has good taste. Curbing 0-11 ft.
Do.	SW. corner SS. slab.	2·0	23·37	Do.	I	81	Irrigates 3 acres by 2 motes. Water has good taste. Curbing 0-7 ft.

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
471	0·65 mile N. of Khedoi Mota.	Manikji Goa Mal	Dg	40	15×6	BM	Sandstone . .
472	0·7 mile NN.E. of Khedoi Mota.	Do.	Dg; B	112	16×7	BM	Do. . .
473	0·7 mile NE. of Khedoi Mota.	Velubha Hotiji	Dg	38	13×7	BM	Do. . .
474	0·7 mile NE. of Khedoi Mota.	Mokaji Hanji .	Dg	47	9×6	..	Do. . .
475	0·75 mile NE. of Khedoi Mota.	Govamal Manji	Dg	29	14×7	..	Do. . .
476	0·75 mile NE. of Khedoi Mota.	Premji Hanji .	Dg	34	11×5	BM	Do. . .
477	0·9 mile NE. of Khedoi Mota.	Chandubha Jalan Singh.	Dg	42	9×7	..	Do. . .
478	0·95 mile NE. of Khedoi Mota.	Ishaq . .	Dg	42	9×7	..	Do. . .
479	1 mile NE. of Khedoi Mota.	Budha Mithu .	Dg	44	8×8	BM	Do. . .
480	0·9 mile NE. of Khedoi Mota.	Budha Mithu .	Dg	46	10×6	..	Do. . .
481	0·9 mile NE. of Khedoi Mota.	Jiva Meghji .	Dg	36	9×7	BM	Do. . .
482	0·85 mile NE. of Khedoi Mota.	Himmet Singh Je Singhji.	Dg	48	8×5	BM	Do. . .
483	0·85 mile NE. of Khedoi Mota.	Jiva Meghaji .	Dg	41	8×6	..	Do.
484	0·95 mile N. of Khedoi Mota.	Ladha Kheta .	Dg	33	11×7	BM	Do. . .
485	0·9 mile N. of Khedoi Mota.	Ladha Kheta .	Dg	44	15×7	BM	Do. . .

See footnotes at end of table.

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj.	Mid. SS. slab, E. side.	1·0	23·90	Dec. 5	I	80	Irrigation by 2 motes, working 8 hrs./day for 10 months/year. Curbing 0-9 ft. Water has slightly brackish taste.
Do.	N.E. corner of the well.	1·0	27·10	Do.	I	81	Irrigates 10 acres by 4 motes, working 8 hrs./day for 10 months/year. Curbing 0-10 ft. Water has good taste.
Do.	Mid. proj. SS. slab.	2·0	27·64	Dec. 7	I	..	Irrigates one acre by 3 motes. Curbing 0-15 ft. Water has good taste.
Do.	Mid. SS. slab, S. side.	2·0	25·05	Do.	Un	..	Curbing 0-11 ft. Water has brackish taste.
Do.	Mid. SS. slab, S. side.	2·0	28·55	Do.	Un	..	Curbing 0-10 ft. Water has brackish taste.
Do.	Mid. SS. slab, E. side.	2·0	27·02	Do.	I	..	Irrigates 4 acres by 3 motes. Curbing 0-14 ft. Water has good taste.
Do.	Mid. SS. slab, E. side.	2·0	27·24	Do.	Un	..	Curbing 0-6 ft. Water has brackish taste.
Do.	West side	5·0	27·27	Do.	Un	..	Curbing 0-8 ft. Water has brackish taste.
Do.	Mid. SS. slab, E. side.	2·0	34·09	Do.	I	..	Irrigates 2 acres by 2 motes. Water has good taste. Curbing 0-9 ft.
Do.	Mid. SS. slab, S. side.	3·0	30·94	Do.	Un	..	Abandoned well. Curbing 0-12 ft. Water has brackish taste.
Do.	Northern side of the well.	3·0	28·88	Do.	Un	..	Abandoned well. Curbing 0-13 ft. Water has brackish taste.
Do.	Mid. SS. slab, N. side.	2·0	32·78	Do.	Un	..	Abandoned well. Curbing 0-13 ft. Water has brackish taste.
Do.	Mid. SS. slab, S. side.	2·0	30·46	Do.	Un	..	Abandoned well. Curbing 0-12 ft. Water has brackish taste.
Do.	Mid. SS. slab., S. side.	..	28·92	Dec. 10	I	..	Irrigates 4 acres by 2 motes. Curbing 0-9 ft. Water has good taste.
Do.	Projecting SS. slab.	..	36·10	Do.	I	..	Irrigates 5 acres by 3 motes. Curbing 0-10 ft. Cultivates wheat etc.

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type [1]	Depth (feet)	Dimensions (feet)	Method of lift [2]	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
486	0·95 mile N. of Khedoi Mota.	Ishwarji Hemat Singh.	Dg	44	12×7	BM	Sandstone . .
487	0·85 mile N. of Khedoi Mota.	Miraji Kalyan Singh.	Dg	46	18×7	HC	Do.
488	0·8 mile N. of Khedoi Mota.	Miraji Kalyan Singh.	Dg	45	9×6	..	Do.
489	0·85 mile N. of Khedoi Mota.	..	Dg	31	11×7	..	Do.
490	0·65 mile NNE. of Khedoi Mota.	Nanji Narain .	Dg	38	9×6	BM	Do.
491	0·7 mile NNW. of Khedoi Mota.	Karamsingh Hardas.	Dg	40	9×6	BM	Do.
492	0·7 mile NNW. of Khedoi Mota.	Kuwarji Gangji Mistry.	Dg	38	9×7	BM	White coarse grained sandstone.
493	0·85 mile NNW. of Khedoi Mota.	Government well	Dg	37	15×8	BM	Do.
494	0·8 mile N. of Khedoi Mota.	Harji Gangdas	Dg	45	11×7	BM	Do.
495	0·9 mile NNE. of Khedoi Mota.	Thakur Raghaji Bhagat Singhji	Dg	203	9×7	HC	Do.
496	0·85 mile NNE. of Khedoi Mota.	Do.	Dg	41	13×7	..	Do.
497	0·7 mile NE. of Khedoi Mota.	Lalji . .	Dg	41	12×10	HC	Do.
498	0·65 mile NNE. of Khedoi Mota.	Karamsji Hardas Sutar.	Dg	40	15×10	BM	Do.
499	0·75 mile NE. of Khedoi Mota.	Premji Anda .	Dg	37	11×8	BM	Do.
500	0·25 mile N. of Tuna.	Raghanji Purshottam.	Dg	28	9×8	..	Current bedded pale yellow argillaceous sandstone.

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)			3		
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj.	Northern side of the well.	2·0	33·86	Dec. 10	I	..	Irrigates 4 acres by 3 motes. Curbing 0-11 ft. Water has good taste.
Do.	Mid. proj. SS. slab, E. side.	..	41·15	Do.	I	..	Irrigates 22 acres by HO. Yielding 160 gals./min. Water has good taste.
Do.	Mid. SS. slab, S. side.	..	30·35	Do.	Un	..	Abandoned well. Water has brackish taste. Curbing 0-8 ft.
Do.	Mid. SS. slab, S. side.	..	24·84	Dec. 11	Un	..	Abandoned well. Curbing 0-9 ft.
Do.	Mid. SS. slab, W. side.	3·0	23·53	Do.	I	79	Irrigates 3 acres by 2 motes. Water has good taste. Curbing 0-12 ft.
Do.	Mid. proj. SS. slab, N. side.	3·0	24·34	Do.	I	80	Irrigates 2 acres by one mote. Curbing 0-4 ft. Water has good taste.
Do.	Mid. SS. slab, N. side.	3·0	24·90	Do.	I	82	Irrigates 2 acres by 2 motes. Water has good taste. Curbing 0-6 ft.
Do.	SS. slab, S. side	2·0	25·48	Do.	I	82	Irrigation by 2 motes. Water has good taste. Curbing 0-10 ft.
Do.	Mid. SS. slab, S. side.	2·0	28·57	Do.	I	80	Irrigates about 3 acres by 2 motes. Water has good taste. Curbing 0-12 ft.
Do.	Top of cemented enclosure.	5·0	36·54	Do.	I	83	Irrigates 23 acres by HO. Yielding 300 gals./min. Water has good taste. Curbing 0-15 ft.
Do.	Mid. proj. SS. slab, S. side.	2·0	26·76	Do.	I	..	Abandoned well. Curbing 0-6 ft.
Do.	Mid. proj. SS. slab, N. side.	..	31·37	Do.	I	83	Irrigates 5 acres by HO. Water has good taste. Yields 170 gals./min.
Do.	Mid. proj. SS. slab, SE. side.	3·0	27·13	Do.	I	80	Irrigation by 2 motes. Water has good taste. Curbing 0-12 ft.
Do.	Proj. SS. slab, W. side.	2·0	26·55	Do.	Un	..	Abandoned well.
Manchhar	Mid. SS. slab, S. side.	3·0	22·60	Nov. 23	I & D	76	Step well. Curbing 0-4 ft. Slightly brackish water.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
501	0·6 mile NNE. of Sidungra.	Suleman Hirji .	Dg	45	10×8	BM	Sandstone
502	0·5 mile N. of Sidungra.	Suleman Hirji .	Dg	47	11×10	BM	Do.
503	0·45 mile N. of Sidungra.	Suleman Hirji .	Dg	49	11×12	BM	Do.
504	0·3 mile N. of Sidungra.	Ramji Anand .	Dg	56	9×6	BM	Do.
505	0·4 mile N. of Sidungra.	Ladda Jagga .	Dg	54	13×10	BM	Do.
506	0·3 mile N. of Sidungra.	Devraj Daya .	Dg	60	12×15	BM	Do.
507	0·35 mile N. of Sidungra.	Mavji Nanji .	Dg	53	12×8	BM	Pale brown sandstone, medium to coarse.
508	0·4 mile N. of Sidungra.	Ram Jiwan Das Mistry.	Dg	59	18×8	HC	Sandstone . .
509	0·65 mile NE. of Khedoi Mota.	Hardas Karsan	Dg	36	11×7	..	Do.
510	0·8 mile NE. of Khedoi Mota.	Raghavji Bhupal Singh.	Dg	41	8×6	..	Do.
511	0·85 mile NNE. of Khedoi Mota.	Kesra Savagar .	Dg	41	9×7	..	Do.

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS.
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj	Mid. proj. SS. slab, E. side.	3·0	28·44	Nov. 24	I	82	Irrigates about 3 acres by one mote. Water has good taste. Curbing 0-17 ft.
Do.	Mid. SS. slab, E. side.	2·0	32·88	Do.	I	84	Irrigates about 3 acres by 2 motes. Water has good taste. Curbing 0-16 ft.
Do.	Mid. SS. slab, E. side.	3·0	34·44	Do.	I	83	Irrigates 4 acres by 2 motes. Water has good taste. Curbing 0-18 ft. Water used for cultivation of wheat, millet and vegetables.
Do.	Mid. SS. slab, E. side.	3·0	34·68	Do.	I	82	Irrigates 4 acres by 2 motes, working 8 hrs./day for 10 months/year. Water has good taste and used for cultivation of wheat and vegetables.
Do.	Mid. SS. slab, E. side.	3·0	35·20	Do.	I	83	Irrigates 5 acres by 4 motes. Water has good taste and used for cultivation of wheat, millet and vegetables. Curbing 0-13 ft.
Do.	Mid. SS. slab, S. side.	2·0	40·39	Do.	I	81	Irrigates about 5 acres by 3 motes. Water has good taste. Curbing 0-10 ft.
Do.	Mid. proj. SS. slab, E. side.	2·0	38·19	Do.	I	82	Irrigates 4 acres by 3 motes, working 8 hrs./day for 10 months/years. Water has good taste. Curbing 0-9 ft.
Do.	Mid. proj. SS. slab on the left partition.	1·0	35·20	Do.	I	84	Irrigates 6 acres by HC, working 8 hrs./day for 10 months year. Yields 120 gals./min.
Do.	Mid. SS. slab, E. side.	2·0	25·94	Dec. 16	Un	..	Abandoned well, curbing 0-10 ft. Water has good taste.
Do.	Mid. SS. slab, S. side.	3·0	25·27	Do.	Un	..	Abandoned well. Curbing 0·10 ft. Water has good taste.
Do.	Mid. SS. slab, S. side.	2·0	26·87	Do.	I	..	Irrigation by 2 motes. Water has good taste. Curbing 0-9 ft.

APPEN

Hydrologic data for wells in the Anjar

Well No.	Location	Owner	Type	Depth (feet) 1	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
512	0·9 mile NE. of Khedoi Mota.	Raghavji Bhupat Singh.	Dg	48	14×7	..	Sandstone
513	0·8 mile NE. of Khedoi Mota.	Sutar Bhachu Raoji.	Dg	41	18×8	..	Do.
514	0·75 mile NE. of Khedoi Mota.	Hirji Dhanji .	Dg	41	10×13	..	Do.
515	0·6 mile NE. of Khedoi Mota.	Hardas Karsan Mistry.	Dg	38	9×7	..	Do.
516	0·5 mile NE. of Khedoi Mota.	Hardas Karsan Mistry.	Dg	32	7×6	..	Do.
517	0·5 mile NNE. of Khedoi Mota.	Karamji Hardas Sutar.	Dg	38	11×7	BM	Do.
518	Just N. of Khedoi Mota.	Malugar Narangar.	Dg	26	9×7	BM	Do.
519	Just N. of Khedoi Mota.	Hasan Hasari .	Dg	26	5×6	..	Do.
520	Just W. of Khedoi Mota.	Velubha Hansiji.	Dg	43	9×11	BM	Do.
521	0·1 mile S. of Khedoi Nana.	Harji Dhanji .	Dg	32	9×7	HC	Do.
522	Just S. of Khedoi Nana.	Siddique Abdullah.	Dg	36	9×5	BM	Do.
523	Just SW. of Khedoi Nana.	Vishram Ramji	Dg	37	12×7	BM	Do.
524	Just W. of Khedoi Nana.	Village well .	Dg	35	6×6	..	Do.
525							
526	0·3 mile SW. of Khedoi Mota.	Rathor Premji Jiram	Dg	11	8×9	..	Weathered Trap.
527	0·3 mile SW. of Khedoi Mota.	Rathod Shavaji Jairam.	Dg	11	8×9	..	Do
528	0·3 mile SW. of Khedoi Mota.	Patidar's well .	Dg	12	8×9	..	Do.
529	·5 mile SW. of Khamra.	Madhu Bha Kuwarji.	Dg B	139	21×11	HC	White coarse sandstone.

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use	Tem pera-ture (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of mea-sure-ment (1951)			
	Description	Above land surface (feet)			3		
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj.	Mid. proj. SS. slab, S. side.	2·0	28·14	Dec. 16	Un	..	Abandoned well. Curbing 0-15 ft.
Do.	Mid. SS. slab, S. side.	2·0	33·34	Do.	Un	..	Abandoned well. Curbing 0-7 ft.
Do.	Mid. SS. slab, S. side.	2·0	27·7	Do.	Un	..	Abandoned well. Curbing 0-13 ft.
Do.	Mid. SS. slab, S. side.	..	23·50	Do.	Un	..	Abandoned well. Curbing 0-10 ft. Water has good taste.
Do.	Mid. SS. slab, S. side.	2·0	22·64	Do.	Un	..	Abandoned well. Water has good taste. Curbing 0-9 ft.
Do.	Proj. SS. slab, N. side.	..	22·19	Dec. 17	I	..	Irrigates about 3 acres by 3 motes. Water has good taste. Curbing 0-8 ft.
Do.	Proj. SS. slab, S. side.	10	18·47	Do.	I	..	Seasonal irrigation by one mote. Water has brackish taste.
Do.	Mid. SS. slab, E. side.	..	16·01	Do.	..	..	Abandoned well. Water has brackish taste.. Curbing 0-6 ft.
Do.	Mid. SS. slab, S. side.	..	19·93	Do.	I	..	Irrigation by 2 motes. Water has brackish taste.
Do.	Mid. SS. slab, S. side.	2·0	23·25	Do.	I	..	Irrigates 3 acres by HC. Yields 80 gals./min. Water has good taste.
Do.	Mid. SS. slab, E. side.	2·0	18·64	Dec. 18	I	..	Irrigates 3 acres by 2 motes. Curbing 0-11 ft.
Do.	Proj. SS. slab, N. side.	2·0	21·93	Do.	I	..	Irrigates 3 acres by 2 motes. Water has good taste. Curbing 0-18 ft.
Do.	West side	4·0	27·59	Do.	D	..	Water has good taste. Curbing 0-17 ft.
Deccan	North side	2·0	2·97	Dec. 18	D	..	Washing use.
Do.	North side	0	2·47	Do.	D	..	Well used for washing clothes.
Do.	South side	1·0	4·58	Do.	D	..	Washing and bathing use.
Upper Bhuj.	Mid. SS. slab, NE. side.	2·0	89·84	Dec. 24	I	84	Irrigates 12 acres by HC. Yielding 170 gals./min. Dug 59 ft. and then two open borings one 80 ft. and the other 46 ft. deep.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
530	0·65 mile SW. of Khamra.	Devji Kuwarji	Dg B	99	9×7	HC	White coarse sandstone.
531	0·75 mile SW. of Khamra.	Bachhu Jusa	Dg	38	14×7	..	White coarse sandstone.
532	0·5 mile SW. of Khamra.	..	Dg	33	4×4	..	White coarse sandstone.
533	0·7 mile SW. of Khamra.	..	Dg	41	8×6	..	White coarse Sandstone.
534	0·9 mile SW. of Khedoi Mota.	..	Dg	33	8×5	..	White sandstone, siltstone and shale.
535	0·8 mile SSW. of Khamra.	..	Dg	34	8×6	..	Sandstone and purple shales.
536	0·05 mile S. of Khamra.	Khengar Nanji	Dg B	130	10×7	BM	Sandstone.
537	0·2 mile S. of Khamra.	..	Dg	39	10×5	..	Do.
538	0·25 mile of Khamra.	..	Dg	41	10×7	..	Do.
539	0·25 mile S. of Khamra.	Vatharam Raja	Dg	40	8×6	BM	Do.
540	0·3 mile S. of Khamra.	..	Dg	42	9×7	BM	Do.
541	0·2 mile E. of Khamra.	Dalji Bha	Dg	54	15×8	BM	Do.
542	0·25 mile E. of Khamra.	..	Dg	50	16×8	BM	Do.
543	0·15 mile E. of Khamra.	Jairam Kheta	Dg	52	11×9	BM	Do.

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj	Mid. SS. slab, NE. side.	1·0	42·80	Dec. 24	I	84	Irrigaties 30 acres by HC Yielding 120 gals./min. Water has good taste. Dug 49 ft. and then one open boring 50 ft. deep.
Do.	Mid. SS. slab, NE. side.	1·0	33·95	Do.	Un	..	Abandoned well. Curbed 0-4 ft.
Do.	Mid. SS. slab, N. side.	2·0	32·34	Do.	D	..	Brackish water.
Do.	Mid. SS. slab, E. side.	1·0	36·85	Do.	Un	..	Curbed 0-7 ft.
Do.	Mid. SS. slab, E. side.	1·0	32·06	Do.	Un	..	Abandoned well. Water has good taste.
Do.	Mid. SS. slab, E. side.	0	30·46	Do.	Un	..	Abandoned well. Water has good taste.
Do.	Mid. SS. slab, NE. side.	2·0	43·50 (pumping).	Dec. 25	I	82	Irrigates 3 acres by 2 motes. Dug 50 ft. and then one open boring 80 ft. deep. Curbing 0-13 ft. Water has good taste.
Do.	Mid. SS. slab, E. side.	1·0	38·74	Do.	Un	..	Abandoned well. Water has good taste. Curbing 0-6 ft.
Do.	Mid. SS. slab, E. side.	2·0	32·66	Do.	Un	..	Abandoned well. Water has good taste. Curbing 0-6 ft.
Do.	Mid. SS. slab, NE. side.	3·0	36·80	Do.	Un	83	Irrigates 3 acres by one mote, working 8 hrs. day for 10 months/year. Curbing 0-6 ft. Water has good taste.
Do.	Mid. SS. slab, W. side.	2·0	34·52	Do.	Un	..	Abandoned well. Water has good taste. Curbing 0-5 ft.
Do.	Mid. SS. slab, E. side.	2·0	40·69	Do.	I	..	Irrigates 3 acres by 2 motes. Water has good taste. Curbing 0-17 ft.
Do.	Mid. SS. slab, E. side.	2·0	36·67	Do.	Un	..	Abandoned well. Water has good taste. Curbing 0-8 ft.
Do.	Mid. SS. slab, E. side.	2·0	41·20	Do.	I	82	Irrigates 2½ acres. Water has good taste. Curbing 0-7 ft.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
544	0·15 mile E. of Khamra.	Ranchhor Pancha.	Dg	54	9×7	BM	Sandstone.
545	Just South of Khamra.	Meghji Raja	Dg B	54	9×11	HC	White coarse sandstones.
546	0·4 mile W. of Khamra.	..	Dg	38	8×4	..	White coarse sandstone.
547	0·2 mile W. of Khedoi Mota.	Kuwarji Anda Mistry.	Dg	208	20×10	HC	White coarse sandstone.
548	Just West of Khamra.	Devaji Jutha	Dg	52	9×9	BM	White coarse sandstones.
549	Just West of Khamra.	Triku Jutha	Dg	47	10×7	BM	White coarse sandstones.
550	0·5 mile SW. of Galpadar.	..	Dg	37	12	..	Mottled yellowish brown and white sandstone.
551	0·9 mile W. of Galpadar.	Bachu	Dg,B	138	9·5 dia	BM	Do.
552	1·1 miles WSW. of Galpadar.	..	Dg	51	8×6	..	Do.
553	1·0 mile N. of Khamra.	..	Dg	43	6·5×6·5	..	Soft, white to buff cross bedded SS.
554	1·15 miles SSE. of Bhadroi.	..	Dg	46	6×7	..	Soft friable, white current-bedded coarse SS.
555	1·2 miles S. of Nigal.	..	Dg	44	7×5·5	BM	Thin bedded SS, siltstones and shales.

See foot notes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)	3		
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj.	Mid. SS. slab, E. side.	2·0	41·60	Dec. 25	I	80	Irrigates 8 acres. Water has good taste. Curbing 0-7 ft.
Do.	Mid. proj. SS. slab, E. side.	1·0	51·39 (pumping).	Do.	I	83	Irrigates 5 acres by HO. yielding 120 gals./min. Water has good taste. Curbing 0-8 ft. Irrigates wheat, millet and vegetables.
Do.	Mid. proj. SS. slab, E. side.	2·0	34·76	Dec. 27	Un	..	Abandoned well, water has brackish taste.
Do.	Mid. proj. SS. slab, E. side.	2·0	47·16	Do.	I	84	Irrigates 15 acres by HO. Yielding 170 gals./min. Water has good taste. Dug 53 ft. and then one boring 150 ft. deep.
Do.	Mid. SS. slab, S. side.	..	35·73	Dec. 31	I	..	Irrigates about 2 acres by 2 motes. Water has brackish taste, Curbing 0-11 ft.
Upper Bhuj.	Mid. SS. slab, E. side.	2·0	39·06	Do.	I	..	Irrigates 2 acres by 2 motes, working 10 hrs./day for 10 months/year. Water has good taste.
Manchhar.	Top of SS. slab, @ chute, E. side.	2·0	25·80	Dec. 18	Un	..	Curbing 0-20 ft. Water has slightly brackish taste.
Do.	Top of highest point on SS. slab, E. side.	..	40·48	Do.	I	..	Irrigates 2 acres by one mote. Water has good taste. Dug 58 ft. and then one open boring 80 ft. deep. Raises all types of grains and vegetables, beets, carrots, etc. Plenty of water for 2 motes.
Do.	Top edge of SS. chute below windlass, N. side.	1·0	37·62	Do.	P	..	Water has brackish taste. Curbing 0-31 ft.
Upper Bhuj.	Top of curb, N. side.	0	42·38	Dec. 22	Un	..	Curbed 0-13 ft.
Do.	Top of proj. SS. slab, N. side.	0	46·0	Do.	Un	..	Abandoned. Curbed 0-13 ft.
Lower Bhuj series.	Top of proj. SS. slab, E. side.	1·0	36·07	Dec. 23	I	81	Irrigates 2½ acres by one mote. Water has good taste. Curbed 0-7 ft.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type	Depth (feet)	Dimensions (feet)	Method of lift	Nature of water-bearing material
			1			2	
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
556	1·0 mile S. of Nigal.	Jesang . .	Dg	46	7×5	BM	Fine reddish brown SS. with grey siltstone bands.
557	0·85 mile E. of Malingna.	Bhoja Mumaya	Dg	39	14×7	BM	Fine reddish brown SS. with grey siltstone bands.
558	0·4 mile E. of Malingna.	Babu Yadogi .	Dg	43	6½×5¼	BM	Finegrained SS. capped by variegated shale and silty shale.
559	0·5 mile E. of Wada.	..	Dg	27	9×5	BM	Medium grained reddish brown sandstone.
560	0·4 mile N. of Bhadrol.	..	Dg	66	7×6	..	Coarse white, friable x-bedded ss. with occas. partings of medium and fine SS. or siltstone.
561	0·45 mile NE. of Malingna.	..	Dg	54	11×6	..	Fine grained SS. with shales.
562	0·5 mile N. of Malingna.	Amir Jiva .	Dg	57	7×5	BM	Fine to med. brown SS. interbedded with varieg. shales.
563	1·3 mile NE. of Nigal.	Bhigal Babu .	Dg	58	12×7	BM	Thin bedded fine SS. alternating with shales.
564	1·0 mile NE. of Nigal.	Dana Duna .	Dg	56	7×6	BM	Fine grey sandstone and alternating shales.
565	1·4 mile NE. of Nigal.	..	Dg	60	8×5½	BM	Thin bedded ferruginous SS. with shales.
566	1·2 mile NNE. of Nigal.	Adu Laxman .	Dg	61	11×6	BM	Variegated shales with thin sandstone.
567	Just North of Khamra.	Kan ji Nanji .	Dg	42	9×8	BM	Sandstone.
568	Just North of Khamra.	Kan ji Nanji .	Dg	43	..	..	Do.

See footnotes at end of table.

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1951)			
	Description	Above land surface (feet)			3		
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Lower Bhuj series.	Top of proj. SS. slab, centre, E. side.	0	30·06	Dec. 23	Un	..	Unused or irrigated at times. Water has good taste.
Do.	Top of proj. SS. slab, centre, W. side.	4·0	35·17	Do.	I	84	Irrigates one acre by one mote. Water has brackish taste. Curbing 0-14 ft. Irrigates wheat. Just enough water for one mote.
Do.	Top of centre SS. proj. slab, E. side.	0	39·94	Dec. 26	I	85	Irrigates 6 acres by 2 motes. Water has very slightly brackish taste. Curbing 0-7 ft. Sufficient water for 2 motes.
Do.	Top of SS. proj. slab, centre W. side.	0	21·56	Dec 29	I	..	Irrigation part of year. Water has good taste. Curbing 0-7¼ ft.
Upper Bhuj.	Top of proj. SS. slab, NE. side.	0	63·32	Dec. 30	Un	..	Curbing 0-3 ft. open below.
Lower Bhuj.	Top of proj. SS. slab, W. side.	2·0	41·28	Do.	Un	..	Curbing 0-22 ft. Water clear and has good taste.
Do.	Top of proj. SS. slab, centre, N. side.	2·0	50·99	Do.	I	..	Irrigates 3 acres by 2 motes. Irrigate wheat, millet and carrots. Curbing 0-11 ft.
Do.	Top of proj. SS. slab, centre, SW. side.	2·0	43·89	Do.	I	..	Irrigates 2·5 acres by one mote. Water has good taste.
Do.	Top of proj. SS. slab, N. side.	1·0	47·47	Do.	I	84	Irrigates 3 acres by one mote. Curbing 0-16 ft. Water has good taste.
Do.	Top of proj. SS. slab, centre, W. side.	1·0	44·69	Do.	I	..	Irrigation at times. Water has good taste. Curbing 0-3½ ft.
Do.	Top of proj. SS. slab, centre, E. side.	1·0	55·24 (pumping).	Do.	I	..	Irrigates 4 acres by one mote. Irrigates wheat, millet and carrots. Water just sufficient for one mote. Curbing 0-8 ft.
Upper Bhuj.	Top of Mid. proj. SS. slab, side.	2·0	39·05	Dec. 31	I	..	Irrigates 3 acres by 2 motes. Water has good taste. Curbing 0-2 ft.
Do.	Top of Mid. SS. slab, E. side.	..	32·30	Do.	Un	..	Abandoned well. Water has brackish taste. Curbing 0-5 ft.

APPEN

Hydrologic data for wells in the Anjar

Well No.	Location	Owner	Type [1]	Depth (feet)	Dimensions (feet)	Method of lift [2]	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
569	0·15 mile ENE. of Khamra.	Khemji Nanji	Dg	53	12×8	BM	Coarse white sandstone.
570	0·25 mile NE. of Khamra.	Khengar Valji	Dg	62	13×8	HC	Do.
571	0·2 mile E. of Khamra.	Hira Pancha .	Dg	45	10×7	BM	Do.
572	0·3 mile E. of Khamra.	Triku Jatta .	Dg	50	8×6	BM	Do.
573	0·4 mile E. of Khamra.	Jetha Bhima .	Dg	49	10×7	BM	Do.
574	0·4 mile E. of Khamra.	Raja Varja .	Dg	50	10×7	BM	Do.
575	0·45 mile E. of Khamra.	Raja Ramji .	Dg	53	13×6	BM	Do.
576	0·5 mile E. of Khamra.	Karman Dana .	Dg	54	15×6	BM	Do.
577	0·5 mile E. of Khamra.	Lala Uka .	Dg	49	9×7	BM	Sandstone .
578	0·2 mile E. of Khamra.	....	Dg	43	10×7	..	Do.
579	0·2 mile E. of Khamra.	....	Dg	37	8×6	..	Do.
580	0·6 mile E. of Khamra.	Hirji Ramji .	Dg	51	8×7	BM	Do.
581	0·65 mile E. of Khamra.	....	Dg	42	10×6	..	Do.
582	0·35 mile E. of Khamra.	....	Dg	52	12	BM	Do.
583	Just E. of Khamra	Raghu Ananda Mistry.	Dg	46	8×6	BM	Do.

See footnotes at end of table.

DIX 14 *contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1952)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj	Top of proj. SS. slab, E. side.	2·0	32·79	Feb. 10	I	..	Irrigation part of year. Water has good taste. Curbing 0-7 ft.
Do.	Top of SS. slab, W. side.	2·0	36·07	Feb. 11	I	..	Irrigation by HC. Yields 120 gals/min. Water has good taste. Curbing 0-10 ft.
Do.	Top of SS. slab, E. side.	2·0	34·70	Do.	I	..	Seasonal irrigation by one mote. Water has good taste. Curbing 0-8 ft.
Do.	Do. . .	2·0	33·91	Do.	I	..	Seasonal irrigation by one mote. Curbing 0-7 ft.
Do.	Do. . .	3·0	35·20	Do.	I	..	Irrigation by 2 motes. Water has good taste. Curbing 0-9 ft.
Do.	Top of Mid. SS. slab, E. side.	2·0	34·34	Do.	I	80	Seasonal irrigation. Water has good taste. Used for the irrigation of millet only.
Do.	Top of Mid. proj. SS. slab, E. side.	2·0	34·61	Do.	I	83	Irrigates 5 acres by one mote. Water has good taste.
Do.	Do. . .	3·0	36·54	Do.	I	83	Irrigates 5 acres by 2 motes. Water has good taste. Curbing 0-7 ft.
Do.	Do. . .	2·0	32·79	Do.	I	83	Irrigates 3 acres by 2 motes. Water has good taste. Curbing 0-9 ft. Irrigates wheat, millet and carrot, etc.
Do.	Top of platform, N. Side.	2·0	33·05	Jan. 1	Un	..	Abandoned well. Curbing 0-5 ft.
Do.	Top of Mid. Proj. SS. slab, E. side.	2·0	32·38	Do.	Un	..	Abandoned well. Water has good taste. Curbing 0-6 ft.
Do.	Top of Mid. Proj. SS. Slab, W. side.	2·0	38·30	Feb. 11	I	82	Irrigates 3 acres by one mote. Water has good taste. Curbing 0-9 ft.
Do.	Top of Mid. Proj. SS. slab, E. side.	3·0	37·63	Do.	Un	..	Abandoned well. Water has good taste. Curbing 0-8 ft.
Do.	Top of proj. SS. slab, E. side.	1·0	32·58	Do.	I	..	Irrigation by 2 motes. Water used for the irrigation of millet only. Curbing 0-10 ft.
Do.	Do. . .	1·0	43·79	Feb. 10	I	83	Irrigation by 2 motes. Water has slight brackish taste.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
584	Just E. of Khamra	Raghu Ananda Mistry.	Dg	47	11×5	BM	Sandstone .
585	0·05 mile E. of Khamra.	Ladhu Kheta .	Dg	55	10×8	BM	Do.
586	0·9 mile SW. of Samparda.	Desan Jetha .	Dg	78	11×5	BM	Do.
587	Just S. of Khamra	Kalji . .	Dg	47	8×7	BM	Do.
588	Located in the Southern half of Khamra.	Village well .	Dg	37	5×4	..	Do.
589	Just E. of South Khamra.	Ananda Nanji .	Dg	47	6×6	BM	Do.
590	0·1 mile E. of South Khamra.	Karamsi Daya .	Dg	46	15×12	HC	Do.
591	Middle of Khamra	Village well .	Dg	39	6×6	..	Do.
592	Just W. of Khamra	Premji Nanji	Dg	46	14×8	..	Do.
593	0·9 mile SW of Samparda.	Viri Vala . .	Dg	77	6×8	BM	Do.
594	1·0 mile SW. of Samparda	Do. . .	Dg	80	8×5	BM	Do.
595	0·9 mile SW. of Samparda.	Kara Mala .	Dg	80	8×5	BM	Do.
596	1·0 mile SW. of Samparda.	Rama Hira .	Dg	78	8×5	BM	Do.
597	0·3 mile NE. of Bhadroi.	Bhima Soja .	Dg	81	9×7	BM	Do.
598	0·35 mile NNE. of Bhadroi.	Kara Hamir .	Dg	78	12×5	BM	Do.

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Tem-perature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1952)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj	Top of Mid. proj. SS. slab, E. side.	2·0	40·41	Feb. 10	I	84	Irrigates 13 acres by 4 motes. Water has slightly brackish taste. Curbed 0-6 ft.
Do.	Do. . .	2·0	43·68	Jan. 1	I	..	Irrigates 3 acres by 2 motes. Water has good taste. Curbing 0-7 ft.
Do.	Do. . .	2·0	74·29	Feb. 12	I	84	Irrigates 4 acres by 2 motes. Water has good taste. Curbing 0-5 ft.
Do.	Do. . .	2·0	37·09	Jan. 2	I	..	Irrigates 3 acres by 2 motes Water has good taste. Curbing 0-8 ft.
Do.	Top of platform, N. side.	2·0	36·60	Do.	D	..	Curbing 0-8 ft.
Do.	Top of Mid. SS. slab, E. side.	2·0	39·77	Do.	I	..	Irrigates about 3 acres by one mote. Water has good taste. Curbing 0-7 ft.
Do.	Top of proj. slab.	..	38·64	Do.	I	79	Irrigates 4 acres by HC. Yielding 60 gals./min. Water has good taste. Curbing 0-10 ft.
Do.	Top of Mid. proj. SS. slab, N. side.	..	33·10	Do.	Un	..	Abandoned well. Water has good taste. Curbing 0-10 ft.
Do.	Top of Mid. proj. SS. slab, W. side.	..	87·20	Do.	Un	..	Abandoned well. Water has brackish taste. Curbing 0-10 ft.
Do.	Top of Mid. proj. SS. slab, E. side.	1·0	71·51	Feb. 12	I	..	Irrigates 5 acres by one mote. Water has good taste. Curbing 0-8 ft.
Do.	Do. . .	2·0	69·69	Do.	I	79	Irrigation part of year by one mote. Curbing 0-8 ft.
Do.	Do. . .	2·0	74·24	Do.	I	83	Irrigates ½ acre by one mote. Water has good taste. Curbing 0-5 ft.
Do.	Do. . .	2·0	74·45	Do.	I	83	Irrigation by one mote. Water has good taste. Cultivates wheat, millet, etc.
Do.	Do. . .	2·0	78·10	Do.	I	..	Irrigates 2 acres by one mote. Water has good taste. Curbing 0-6 ft.
Do.	Do. . .	2·0	75·97	Do.	I	84	Irrigates 2 acres by one mote. Water has good taste.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
599	0·3 mile N. of Bhadroi.	Megar Mana	Dg	80		BM	Sandstone.
600	1·5 mile E. of Shinaya.	Suji Bhima	Dg	46	9×5	BM	Current-bedded sandstone.
601	1·7 mile ESE of Shinaya.	Ramji Mulla	Dg	44	9×5	BM	Current-bedded Sandstone.
602	1 mile W. of Kidana.	Meharam Kingar	Dg	38	10½×5½	BM	Do.
603	0·65 mile SW. of Kidana.	Samath Ramji	Dg	31	9½×6½	BM	Do.
604	0·35 mile SW. of Kidana.	Kana Jesan	Dg	28	7½×7	BM	Do.
605	0·8 mile S. of Kidana.	....	Dg	22	10×9	BM	Do.
606	0·35 mile W. of Barapur.	....	Dg	30	10×7	BM	Do.
607	0·7 mile NW. of Barapur.	Mabo	Dg	28	8×6½	BM	Fossiliferous conglomeratic sandstone.
608	0·9 mile NW. of Barapur.	Hirji	Dg	32½	6×6	BM	Inter-bedded coarse SS. and fine silty SS.
609	0·75 mile N. of Devalia.	....	Dg	10	6	..	Soft brown trap.
610	1·8 mile E. of Midiada.	....	Dg	24	8	..	Broken trap.
611	0·75 mile N. of Kumbharia.	....	Dg	7	3½×3½	..	Soft earthy amygdular trap.

See footnotes at end of table

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1952)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj	Top of Mid. proj. S.S. slab, E. side.	1·0	72·10	Feb. 12	I	82	Irrigates 3 acres by one mote. Water has good taste. Curbing 0-4 ft.
Manchhar	Top of Mid. SS. slab, E. side.	0	32·63	Jan. 2	I	80	Irrigates 3 acres by one mote. Water has brackish taste. Curbing 0-7 ft.
Do.	Top of proj. SS. slab, centre, E. side.	2·0	22·76	Do.	I	81	Irrigates 4 acres by 2 motes. Water has very brackish taste. Irrigates wheat, millet, carrots and large radishes. Curbing 0-8 ft.
Do.	Top of proj. SS. slab, centre, N. side.	3·0	31·90	Do.	I	81	Irrigates 2 acres by one mote. Water has brackish taste. Irrigates wheat and millet. Curbing 0-11 ft.
Do.	Top of proj. SS. block.	0	26·09	Do.	I	80	Irrigates 3 acres by one mote. Water has brackish taste. Irrigates wheat and millet. Curbing 0-10 ft.
Do.	Top of proj. SS. slab, S. side.	2·0	22·77	Jan. 4	I	80	Irrigates one acre by one mote. Water has brackish taste. Curbing 0-6½ ft. Irrigates wheat—good stand.
Do.	Top of proj. SS. slab, centre, E. side.	2·0	13·73	Do.	I	..	Irrigation by one mote. Water has brackish taste. Irrigates wheat and millet.
Do.	Top of W. proj. S.S. slab, S. side.	0	17·44	Do.	I	81	Irrigation by one mote. Water has very brackish taste. Curbing 0-12 ft. Irrigating wheat which does not appear to be doing well.
Do.	Top of proj. SS. slab, centre, W. side.	0	24·71	Do.		83	Irrigation by one mote. Water has brackish taste. Curbed 0-5½ ft. Irrigating wheat—meagre stand.
Do.	Top edge of chute @pulley, S. side.	0	21·49	Do.	I	81	Irrigates 2 acres by one mote. Water has very brackish taste. Curbing 0-6½ ft. Irrigates wheat and also millet.
Deccan	Top of masonry ring.	2·0	4·88	Jan. 5	P	..	Public well. Curbed to water level.
Do.	Top of proj. SS. slab, E. side.	0·5	11·97	Jan. 6	P	..	Public road side well, Curbed 0-12 ft.
Do.	Top of Curb, E. side.	2·0	4·48	Do.	P	..	Water—pale yellow—brackish taste. Curbing 0-7 ft.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
612	0·05 mile E. of Kumbharia.	....	Dg	6	4½	..	Coarse sand and gravel - perhaps 5-20 ft. thick.
613	0·6 mile SE. of Bhuyad.	....	Dg	33	9½×9½	..	Soft trap.
614	0·6 mile W. of Bhuyad.	Muku . .	Dg	33	10×7	BM	Do.
615	0·4 mile S. of Bhuyad.	Toja Baba .	Dg	42	11×7	BM	Soft jointed trap
616	1·4 miles NE. of Bhuyad.	....	Dg	8½×4½	..	..	Sand and gravel
617	0·8 mile S. of Samparda.	Bhima Jiwan .	Dg	64	8×6	BM	White to buff arg. coarse sandstone.
618	0·55 mile SW. of Samparda.	Shiva Jehta .	Dg.	69	7½×6	BM	Do.
619	0·9 Mile W. of Samparda.	Bechu Patel .	Dg	86	11×6	..	Do.
620	Do. . .	....	Dg	59	7×6	..	Do.
621	1·0 mile NE. of Mathada.	Issa Hamir .	Dg	46	9×6	BM	Coarse white sandstone.
622	0·9 mile NNE. of Mathada.	Mamu Husen .	Dg, B	130	10×6	BM	Do.
623	0·85 mile NE. of Mathada.	Ibraham Chagha	Dg	130	11×7	BM	Do.
624	0·8 mile N. of Mathada.	Hazi Ismail .	Dg	45	10×7	BM	Do.
625	0·6 mile N. of Mathada.	....	Dg	35	8×5	BM	Do.

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1952)			
	Description	Above land surface (feet)			3		
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Recent alluvium	Top of curb, N. side.	2·0	4·38	Jan. 13	P	..	Water has good taste, all curbed.
Deccan	Top of SS. slab, centre, E. side.	2·0	17·99	Jan. 14	Un	..	Curbed to water level. Water has good taste.
Do.	Do.	..	29·50	Do.	I	..	Irrigates one acre by one mote. Water has brackish taste. Curbing 0-18 ft.
Do.	Do.	0	31·48	Do.	I	..	Irrigates one acre by one mote. Water has clear slightly brackish taste. Curbing 0-27 ft.
Recent alluvium	Top of curb, N. side.	1·0	6·18	Do.	P	..	Taps under flow of *Nala* Water has good taste.
Upper Bhuj	Top of SS. slab, centre, E. side.	2 0	58·94	Jan. 15	I	85	Irrigates 2 acres by one mote. Water has good taste. Cultivates all types of vegetables and cereals.
Do.	Top of SS. slab, centre, NE. side.	2·0	66·18	Do.	I	84	Irrigates 4 acres by one mote. Water has good taste. Curbed 0-8½ ft. Water sufficient for one mote.
Do.	Top of Mid. proj. SS. slab, N. side.	..	86·4 (?)	Feb. 14	..	..	Dry well.
Do.	Top of SS. slab, centre, W. side.	1·0	55·00	Jan. 18	I	..	Seasonal irrigation. Unused at present.
Do.	Top of proj. SS. slab, E. side.	1 0	39·57	Jan. 27	I	..	Irrigates one acre by one mote working 8 hrs. day for 6 months/year. Water has good taste.
Do.	Top of proj. SS. slab, S. side.	2·0	39·90	Do.	I	85	Irrigates 2 acres by 2 motes. Water has good taste. Dug 50 ft. and then one open boring 80 ft. deep. Curbing 0-12 ft.
Do.	Top of Mid. proj. SS. slab, E. side.	2·0	31·30	Do.	I	85	Irrigates 1¼ acres by 2 motes. Water has good taste. Dug 40 ft. and then two borings 90 ft. deep.
Do.	Top of Mid. proj. SS. slab, E. side.	2·0	40·49	Do.	I	85	Irrigates 2 acres by 2 motes. Water has good taste. Produces wheat, bajri and vegetables.
Do.	Top of Mid. proj. SS. slab, S. side.	2·0	23·06	Do.	I		Irrigates 1 acre by one mote. Water has slightly brackish taste. Curbed 0-18 ft.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type [1]	Depth (feet)	Dimensions (feet)	Method of lift [2]	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
626	0·5 mile NE. of Mathada.	Jamal Yusuf .	Dg.	31	10×6	BM	Coarse white Sandstone.
627	0·7 mile N. of Mathada.	Budha Hazi .	Dg	38	7½×7½	BM	Do.
628	0·7 mile NE. of Mathada.	Jasa Taga .	Dg	37	12×9	BM	Do.
629	0·8 mile NNE. of Mathada.	Saddiq Ibrahim	Dg	108	12×7	BM	Do.
630	1·0 mile NE. of Mathada.	Rava Kuja Patel	Dg	42	11×6	BM	Do.
631	0·4 mile NE. of Mathada.	....	Dg	22	8×7	BM	Do.
632	0·65 mile SW. of Samparda.	Rama Rata .	Dg	73	8×5	BM	Do.
633	0·7 mile SW. of Samparda.	Ala Rama .	Dg	74	7×6	BM	Brown coarse Sandstone.
634	0·8 mile SW. of Samparda.	Sava Rania .	Dg	73	10×6	BM	White coarse Sandstone.
635	Do. .	Bechar Mamaya	Dg	75	11×6	BM	Do.
636	0·85 mile SW. of Samparda.	Rakha Mara .	Dg	78	8×6	BM	Do.
637	1·0 mille SW. of Samparda.	Chowtha Bala .	Dg	75	8×6	BM	Do.
638	1·1 miles SW. of Samparda.	Rava Rama .	Dg	80	9×6	BM	Do.
639	0·3 mile E. of Bhadroi.	Daya Shankar Shyamji.	Dg	74	8×6	..	Do.
640	0·3 mile E. of Bahdroi.	Do. . .	Dg	76	19×10	..	Do.

See footnotes at end of table.

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1952)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj	Top of mid, proj. SS. slab, S. side	2·0	29.33	Jan. 27	I	84	Irrigates ½ acre by one mote. Water slightly brackish taste. Cultivates wheat and millet.
Do.	Top of mid. proj. SS. slab, W. side.	2·0	27·32	Do.	I	83	Irrigation by 2 motes. Water has good taste. Curbing 0-12- ft.
Do.	Top of mid. proj. SS. slab, E. side.	2·0	34·14	Do.	I	82	Irrigates 2 acres by 2 motes. Water has good taste. Cultivates wheat, millet and carrots.
Do.	Do.	..	30·58	Do.	I	..	Irrigates 2 acres by 2 motes. Water has good taste. Curbing 0-11 ft.
Do·	Do.	2·0	34·61	Do.	I	88	Irrigates 5 acres by 2 motes. Water has good taste. Curbing 0-8 ft.
Do.	Top of mid. proj. SS. slab, S. side.	1·0	12·37	Do.	I	..	Seasonal irrigation by one mote. Water has good taste.
Do.	Top of mid proj. SS. slab, E. side.	2·0	66·07	Feb. 4	I	83	Irrigation by one mote. Water has good taste. Curbing 0-8½ ft.
Do.	Top of mid. proj. SS. slab, E. side.	2·0	64·46	Do.	I	84	Irrigation by 2 motes. Water has good taste. Curbing 0-5 ft. Cultivates wheat and millet.
Do.	Do.	..	66·59	Do.	I	..	Irrigation by one mote. Water used for the irrigation of wheat and millet.
Do.	Do.	1·0	65·08	Do.	I	81	Irrigation by 2 motes. Water has good taste. Irrigates wheat and millet. Curbing 0-6 ft
Do.	Do.	2·0	63·78	Do.	I	85	Irrigation by 2 motes. Water has good taste. Curbing 0-6 ft.
Do.	Top of proj. SS. slab. E. side.	2·0	64·86	Do.	I	84	Irrigates 4 acres by one mote. Water has good taste. Curbing 0-5 ft.
Do.	Top of mid proj. SS. slab, E. side.	2·0	65·11	Do.	I	83	Irrigation by 2 motes. Water has good taste. Curbing 0-4 ft.
Do.	Do.	2·0	64·46	Do.	Un	..	Water has good taste. Curbing 0-5 ft.
Do.	Do.	2·0	68·62	Do.	Un	..	Curbing 0-8½ ft.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E	F)	(G)	(H)
641	0·6 mile SW. of Samparda.	Jaga Rama .	Dg	71	8×6	BM	White coares Sandstone.
642	0·6 mile SSW. of Samparda.	Rana Rura .	Dg		8×8	BM	Do.
643	0·65 mile SSW. of Samparda.	Rakha Bhima	Dg	66	9×6	BM	Coarse brown Sandstone.
644	0·75 mile SSW. of Samparda.	Vala Hire	Dg	65	9×6	BM	Do.
645	0·7 mile SSW. of Samparda.	Guda Ruya	Dg	66	10×6	BM	Do.
646	0·8 mile SSW. of Samparda.	Jaisingh Panchar	Dg	66	11×5	BM	Do.
647	Do.	Vala Hira .	Dg	76	12×6	BM	Do.
648	0·7 mile SW. of Samparda.	Nagu Bijal .	Dg	71	12×5	BM	Do.
649	0·65 mile SW. Samparda.	Chautha Rura .	Dg	72	12×6	BM	Do.
650	0·7 mile SW. of Samparda.	Bhima Seja .	Dg	75	8×6	BM	Do.
651	0·75 mile SW. of Samparda.	Ganga Rura .	Dg	80	8×7	BM	Coarse white Sandstone.
652	0·8 mile SW. of Samparda.	Teja Bhima .	Dg	75	14×7	BM	Do.
653	0·85 mile SW. of Samparda.	Ganga Rura .	Dg	77	8×5	BM	Do.
654	Just East of Sidungra.	Khoja Sachedina Karim.	Dg	58	11×9	BM	Do.

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1952)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj	Top of mid. proj. SS. slab, NE. side.	2·0	65·08	Feb. 5	I	83	Irrigation by one mote. Water has good taste. Curbing 0-14 ft.
Do.	Do.	2·0	63·35	Do.	I	82	Irrigates 4 acres by 2 motes. Water has good taste. Curbing 0-6 ft.
Do.	Do.	..	63·04	Do.	I	84	Irrigates 6 acres by 2 motes. Water has good taste. Curbing 0-5 ft. Enough water for one mote.
Do.	Top of mid SS. slab, E. side.	2·0	56·65	Do.	I	84	Irrigates 4 acres by 2 motes. Water has good taste. Curbing 0-4 ft.
Do.	Top of SS. slab, E. side.	2·0	57·85	Do.	I	..	Irrigation part of year by single mote. Water has good taste.
Do.	Do.	..	59·52	Do.	I	82	Irrigation by single mote. Cultivates wheat and millet.
Do.	Do.	..	64·08	Do.	I	..	Irrigation by one mote. Compact fine SS. at bottom which does not yield enough water.
Do.	Top of mid. proj. SS. slab, E. side.	2·0	64 31	Do.	I	81	Irrigation by 3 motes. Water has good taste. Curbing 0-5 ft.
Do.	Do.	2·0	64·31	Do.	I	81	Irrigation by 3 motes. Water has good taste. Curbing 0-3 ft.
Do.	Top of SS. slab, E. side.	2·0	71·64	Do.	I	81	Irrigation by 2 motes, Water has good taste.
Do,	Top of mid. proj. SS. slab, E. side.	2·0	74·34	Do.	I	83	Irrigates 3 acres by 2 motes Water has good taste. Cultivates wheat and millet, etc.
Do.	Do.	3·0	72·73	Do.	I	..	Irrigation by 3 motes. Water has good taste. Curbing 0-5 ft.
Do.	Do.	3·0	69·91	Do.	I	84	Irrigation by one mote. Water has good taste. Enough water for one mote. Curbing 0-7 ft.
Do.	Corner SS. slab	1·0	47·54	Feb. 9	I	81	Irrigation by 2 motes. Water has slightly brackish taste. Irrigates wheat, millet and vegetables.

APPEN

Hydrologic data for wells in the Anjar

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
655	NE. corner of Sidungra.	Mistry Daya Chanda.	Dg	61	11×7	BM	Coarse white Sandstone.
656	0·1 mile N. of Sidungra.	Varjag Kheta .	Dg, B	104	18×9	BM	Do.
657	Centre of Sidungra	Village well .	Dg	51	15×9	..	Do.
658	0·1 mile N. of Sidungra.	Ballamji Jairam	Dg	60	15×10	BM	Do.
659	0·05 mile N. of Sidungra.	Sava Bhoja .	Dg.	57	18×9	BM	Do.
660	0·1 mile N. of Sidungra.	Devraj Daya .	Dg	53	13×8	..	Cross bedded brown ferruginous sandstone.
661	0·15 mile N. of Sidungra.	Kishan Jetha .	Dg, B	151	12×7	HO.	Do.
662	0·2 mile N. of Sidungra.	Jivram Jairam .	Dg.	51	10×6	BM	Coarse white sandstone.
663	0·25 mile N. of Sidungra.	Husen Jivraj .	Dg	56	15×9	BM	Do.
664	0·3 mile N. of Sidungra.	Karam Singh Khora.	Dg	52	9×7	BM	Do.
665	0·25 mile N. of Sidungra.	Sava Bhoja .	Dg	47	8×6	BM	Do.
666	0·25 mile NNW. of Sidungra.	Mahmood Kheja	Dg	65	16×8	BM	Sandstone .
667	0·5 mile NE. of Sidungra.	Mistry Hemraj Kanji.	Dg	37	8×6	BM	White coarse sandstone.
668	0·45 mile NE. of Sidungra.	Mistry Hemraj Kanji.	Dg	40	10×7	BM	White coarse sandstone
669	0·4 mile NE. of Sidungra.	Manji Bhoja .	Dg	50	15×6	BM	White coarse sandstone.

See footnotes at end of table.

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1952)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj	Mid. proj. SS. slab, E. side.	0·0	40·76	Feb. 9	I	..	Irrigation by 2 motes. Irrigates wheat millet and vegetables. Curbing 0-11 ft.
Do.	Do.	2·0	37·67	Do.	I	84	Irrigates 4 acres by 3 motes. Dug. 44 ft. and then one open boring 150 ft. deep. Water has good taste.
Do.	Bottom of S. side fence.	2·0	41·79	Do.	D	..	Water has clean good taste. Curbing 0-18 ft. Water used for drinking purpose.
Do.	Mid. proj. SS. slab, E. side.	..	41·87	Do.	I	..	Water has good taste. Irrigation by 2 motes. Curbing 0-10 ft. Irrigates wheat, millet and vegetables.
Do.	Do.	2·0	42·84	Do.	I	..	Irrigation by 2 motes. Curbing 0-13 ft.
Do.	Do.	2·0	40·28	Do.	Un	..	Curbing 0-14 ft.
Do.	Do.	1·0	50·32	Do.	I	83	Irrigation by HO. Yielding 80 gals./min. Working 8 hrs./day for 10 months/year. Irrigates wheat, millet, etc.
Do.	Do.	3·0	38·13	Do.	I	85	Irrigates 2 acres by one mote. Water has good taste. Curbing 0-12 ft.
Do.	Do.	2·0	43·38	Do.	I	84	Irrigates 4 acres by 3 motes. Water has good taste. Curbing 0-13 ft.
Do.	Do.	2·0	40·06	Do.	I	85	Irrigates 2 acres by one mote. Water has good taste. Curbing 0-13 ft.
Do.	Do.	2·0	39·50	Do.	I	..	Irrigates 2 acres by one mote.
Do.	Top of mid· proj. SS. slab, E. side.	2·0	38·14	Do.	I	84	Irrigation by 2 motes. Water has good taste. Curbing 0-15 ft.
Do.	Do.	3·0	24·84	Feb. 10	I	78	Irrigation by 2 motes. Water has brackish taste. Water used for irrigation of wheat and millet.
Do.	Do.	2·0	26·64	Do.	I	81	Irrigation by 2 motes. Water has brackish taste. Curbing 0-16 ft.
Do.	Do.	2·0	27·50	Do.	I	81	Irrigation by 2 motes. Water has brackish taste. Curbing 0-11 ft. Irrigates wheat and millet.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
670	0·4 mile NE of Sidungra.	Manji Bhoja .	Dg	44	9×7	BM	Sandstone . .
671	0·3 mile NE of Sidungra.	Mohammad Imtala.	Dg	146	16×8	BM	Do.
672	0·3 mile NE of Sidungra.	Do.	Dg	74	11×8	BM	Do.
673	..	..	..	..	..	..	
674	0·4 mile N. of Bhadroi.	Radu Mema .	Dg	82	8×5	BM	Do.
675	0·35 mile N. of Bhadroi.	Jisang Rana .	Dg	80	11×5	BM	Do.
676	0·45 mile N. of Bhadroi.	Mema Heja .	Dg	82	11×5	BM	Do.
677	0·5 mile N. of Bhadroi.	Sava Uba .	Dg	77	8×6	BM	Do.
678	0·5 mile N. of Bhadroi.	Jeja Bijal .	Dg	84	8×6	BM	Do.
679	0·55 mile N. of Bhadroi.	Karsan Bijal .	Dg	85	8×6	BM	Do.
680	0·6 mile NNW of Bhadroi.	Jiwa Bhima .	Dg	72	7×5	BM	Do.
681	0·6 mile SW of Samparda.	Bhima Jiwan .	Dg	73	9×7	BM	Do.
682	0·65 mile WSW of Samparda.	Ganga Dana .	Dg	78	8×6	BM	Coarse white sandstone.
683	0·7 mile SW of Samparda.	Jai Singh Jetha	Dg	78	8×7	BM	Do.
684	0·8 mile WSW of Samparda.	Kana Chantha .	Dg	79	8×6	BM	Do.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1952)			
	Description	Above land surface (feet)			8		
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj.	Top of mid. proj. SS. slab, E. side.	3·0	34·74	Feb. 10	I	..	Irrigates 6 acres by 2 motes. Water has good taste. Curbing 0-15 ft. Irrigates wheat and millet.
Do.	Do.	2·0	34·06	Do.	I	81	Irrigates 4 acres by 4 motes. Dug 46 ft. and then one open boring 100 ft. deep. Water has good taste.
Do.	Do.	3·0	37·01	Do.	I	82	Irrigates 2 acres by 2 motes. Water has good taste. Curbing 0-11 ft.
..	..	..	..	..	..	..	
Upper Bhuj	Top of mid. proj. SS. slab, E. side.	2·0	78·40	Feb. 12	I	..	Irrigates one acre by one mote. Water has good taste. Curbing 0-7 ft.
Do.	Top of mid. proj. SS. slab, W. side	1·0	76·75	Do.	I	..	Irrigates 3 acres by 2 motes. Water has good taste. Curbing 0-5 ft.
Do.	Top of mid. proj. SS. slab, E. side.	3·0	74·70	Do.	I	..	Irrigates 2¼ acres by 2 motes. Water has good taste. Curbing 0-5 ft.
Do.	Do.	2·0	74·54	Do.	I	85	Irrigates 1¼ acres by one mote. Water has good taste. Curbing 0-7 ft.
Do.	Top of mid. proj. SS. slab, N. side.	2·0	79·10	Do.	I	85	Irrigates 3 acres by 2 motes. Water has good taste.
Do.	Top of mid. proj. SS. E. side.	3·0	73·80	Do.	I	..	Seasonal irrigation by one mote. Water has good taste. Curbed 0-9 ft.
Do.	Do.	3·0	67·70	Do.	I	..	Seasonal irrigation by one mote. Water has good taste.
Do.	Top of mid. proj. SS. slab, E. side.	2·0	67·22	Feb. 13	I	84	Irrigation by 2 motes. Water has brackish taste. Well does not yield enough water for 2 motes.
Do.	Do.	3·0	70·92	Do.	I	..	Irrigates 2 acres by 2 motes. Water has slightly brackish taste. Curbing 0-6 ft.
Do.	Top of mid. proj. SS. slab, S. side.	2·0	71·58	Do.	I	84	Irrigates about one acre by one mote. Curbing 0-11 ft. Irrigates wheat and millet.
Do.	Top of mid. proj. SS. slab, E. side.	3.0	72·00	Do.	I	84	Irrigates 2 acres by one mote. Water has slightly brackish taste. Curbing 0-9 ft.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type[1]	Depth (feet)	Dimensions (feet)	Method of lift[2]	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
685	0·8 mile SW of Samparda.	Asha Bhima .	Dg	77	8×6	BM	Coarse white sandstone.
686	1·0 mile WSW of Samparda.	Jakhara Sura .	Dg	81	12×6	BM	Do.
687	0·9 mile WSW of Samparda.	Kana Jetha .	Dg	90	11×5	BM	Do.
688	0·9 mile WSW of Samparda.	Vala Rakhia .	Dg	84	9×6	BM	Do.
689	0·95 mile W. of Samparda.	Jiva Allah .	Dg	78½	8×5	BM	Do.
690	0·8 mile SSE of Samparda.	Jai Singh Ranmal.	Dg	68	8×6	BM	Do.
691	0·65 mile SSE of Samparda.	Ala Rama .	Dg	68	8×6½	BM	Sandstone . .
692	0·8 mile S. of Samparda.	Kara Rama .	Dg	67	8½×6½	BM	Do.
693	0·7 mile SSE of Samparda.	Ala Parbat .	Dg	68	9×7	BM	Do.
694	0·85 mile S. of Samparda.	Kara Rama .	Dg	65	8×5	BM	Do.
695	0·1 mile E. of Bhadroi.	Rabari . .	Dg	71	8×6	..	Brown sandstone .
696	0·2 mile E. of Bhadroi.	Village well .	Dg	69	4×6	..	White coarse sandstone.
697	0·1 mile N. of Bhadroi.	..	Dg	70	5×5	..	Brown hard sandstone.
698	0·1 mile NNE of Samparda.	Village well .	Dg	56	5 (dia.)	..	Sandstone . .
699	0·3 mile NW of Berry's Bunglow.	Ahmad . .	Dg	23	8 (dia.)	BM	Mottled sandstone

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use	Tempera-ture (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of mea-surement (1952)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Upper Bhuj	Top of mid. proj. SS. slab, E. side.	2·0	70·05	Feb. 13	I	85	Irrigates 4 acres by one mote. Water has good taste. Curbing 0-6 ft.
Do.	Do.	8·0	76·45	Do.	I	84	Irrigates 3 acres by 2 motes. Water has good taste. Curbing 0-5 ft. Not enough water for 2 motes.
Do.	Do.	2·0	83·81	Do.	I	..	Irrigation by 2 motes. Water has good taste. Curbed 0-6 ft.
Do.	Top of mid. proj. SS. slab, E. side.	2·0	80·87	Do.	I	84	Irrigates 5 acres by 2 motes. Water has good taste. Curbing 0-5 ft.
Do.	Top of SS. slab centre, E. side.	0	73·79	Jan. 15	I	83	Irrigates 2 acres by one mote. Water has good taste. Curbing 0-6 ft.
Do.	Do.	8·0	68·2	Feb. 14	I	..	Irrigates one acre by one mote. Water has good taste.
Do.	Top of mid. proj. SS. slab, E. side.	3·0	62·78	Do.	I	..	Irrigation by single mote for part of year. Curbing 0-17 ft. Water has good taste. Irrigates millet.
Do.	Do.	8·0	58·45	Do.	I	84	Irrigates 7 acres by one mote. Water has good taste. Curbing 0-10 ft. Irrigates wheat and millet.
Do.	Top of mid. proj. SS. slab.	2·0	64·09	Do.	I	83	Irrigates 4 acres by 2 motes. Water has good taste. Curbing 0-5 ft. Irrigates wheat, millet, etc.
Do.	Top of mid. proj. SS. slab, E. side.	2·0	56·88	Do.	I	88	Irrigation by one mote. Water has good taste. Curbing 0-5 ft. Irrigates wheat, millet, etc.
Do.	Do.	2·0	64·08	Do.	Un	..	Abandoned well. Water is dirty but has good taste.
Do.	Top of mid. proj. SS. slab, S. side.	1·0	64·20	Do.	D	..	Curbed 0-10 ft. Water has good taste.
Do.	Top of curb, W. side of well.	0·5	65·52	Do.	D	..	Curbed 0-4 ft. Water is dirty but has good taste.
Do.	Top of SS. slab, E. side.	0	47·43	Feb. 15	D	..	Drinking water well. Clean good taste water.
Manchhar	Do.	0	19·51	Feb. 19	I	81	Irrigates 2 acres by 1 mote. Water has brackish taste. Irrigates wheat, millet, etc.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type[1]	Depth (feet)	Dimensions (feet)	Method of lift[2]	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
700	0·2 mile NNE of Berry's Bunglow.	..	Dg	26	8 (dia.)	BM	Mottled sandstone
701	1·4 miles N. of Nigal.	Rama Dorca .	Dg	75½	8×6	BM	Sandstone with thin intercalated shales.
702	0·7 mile N. of Nigal.	Karsam Natu .	Dg	68½	11×6	BM	Sandstone with thin intercalated shales.
703	2·0 miles NW of Nigal.	Umar Changol .	Dg	54	13×8	BM	Sandstone . .
704	2·6 miles NW of Nigal.	Mol Banwa .	Dg	61½	8½×5½	BM	Do.
705	1·1 miles NW of Nigal.	Rawa Teja .	Dg	77	11×5	BM	Sandstone with thin shales.
706	1·3 miles N. of Nigal.	Mata Govinda Ganga.	Dg	71	7×6½	BM	Brown shaly fine sandstone.
707	1·3 miles N. of Nigal.	Lakhman Bhana	Dg	76	8×6	BM	Do.
708	1·4 miles N. of Nigal.	Mata Daya Bhana.	Dg, B	183	6×3	BM	Do.
709	1·4 miles N. of Nigal.	Jethwa Bhojraj Nathiyi.	Dg	83	8×6	BM	Do.
710	1·3 miles NNW of Nigal.	Lakhman Vasta	Dg	76	8×5	BM	Do.
711	1·3 miles N. of Nigal.	Danu Basta .	Dg	72	8×5	BM	Do.
712	1·3 miles NNW of Nigal.	Mata Deka Teja	Dg, B	185	8×6	BM	Do.
713	1·4 miles NNW of Nigal.	Mata Rawa Dhana.	Dg	81	8×6	BM	Do.

See footnotes at end of table.

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Tem-perature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1952)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Manchhar	Top of SS. slab, S. side.	3·0	17·28	Feb. 19	I	..	Irrigation part of year. Water has brackish taste.
Lower Bhuj.	Top of SS. slab, Centre, E. side.	2·0	72·01	Mar. 24	I	..	Irrigation by one mote. Water not sufficient. Curbing 0-9 ft. Water has good taste.
Do.	Top of central SS. slab, E. side.	3·0	51·41	Do.	I	..	Irrigates 3 acres by one mote. Water has good taste.
Do.	Top of curb, E. side.	3·0	47·90	Do.	I	..	Irrigates 3 acres by 2 motes. Water has good taste. Curbing 0-8 ft. Enough water for 2 motes.
Do.	Top of SS. slab, centre, E. side.	2·0	55·53	Do.	I	..	Irrigates 2 acres by one mote. Water has good taste and is used for all cultivation. Curbing 0-6 ft.
Do.	Do.	2·0	69·09	Do.	I	..	Irrigates 2½ acres by 3 motes. Water has good taste. Curbing 0-10 ft.
Do.	Top of mid. proj. SS. slab, E. side.	1·0	65·47	Apr. 17	I	..	Irrigation by one mote. Water has good taste. Curbing 0-5 ft.
Do.	Do.	1·0	71·65	Do.	I	..	Irrigates 1½ acres by one mote. Water has good taste. Irrigates wheat, millet and fodder.
Do.	Top of mid. proj. SS. slab, W. side.	2·0	76·03	Do.	I	..	Irrigates 2 acres by 2 motes. Water has good taste. Dug 83 ft. and then one open boring 100 ft. deep. Curbing 0-8 ft.
Do.	Do.	2·0	79·9	Do.	I	..	Irrigates 1½ acres by one mote. Water has good taste. Curbing 0-8 ft.
Do.	Top of mid. proj. SS. slab, E. side.	2·0	68·92	Do.	I	..	Irrigates one acre by one mote. Water has good taste.
Do.	Do.	2·0	65·18	Do.	I	..	Irrigates 1¼ acres by one mote. Water has good taste. Curbed 0-8 ft.
Do.	Top of mid. proj. SS. slab N. side.	2·0	72·25	Do.	I	..	Irrigates 2 acres by one mote. Dug 75 ft. and then one 110 ft. deep open boring. Water has good taste.
Do.	Top of mid. proj. SS. slab, E. side	2·0	76·30	Do.	I	..	Irrigates 2 acres by one mote. Water has good taste. Curbing 0·9 ft.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type[1]	Depth (feet)	Dimensions (feet)	Method of lift[2]	Nature of water-bearing material
(A)	(B)	(C	(D)	(E)	(F)	(G)	(H)
714	1·4 miles NNW of Nigal.	Bachu Dana	Dg	79	8×6	BM	Brown shaly sandstone.
715	1·3 miles NNW of Nigal.	Bijal Kara	Dg	71	6×8	BM	Shaly sandstone.
716	1·3 miles NNW of Nigal.	Karsan Deka	Dg	77	6×7	BM	Brownshaly sandstone.
717	1·2 miles NNW of Nigal.	Nathi Bharba	Dg	75	10×6	BM	Brown medium sandstone.
718	1·2 miles NNW of Nigal.	Rana Kara	Dg, B	131	11×6	BM	Do.
719	1·3 miles NNW of Nigal.	Kuru Ganga	Dg	70	9×6	BM	Do.
720	1·2 miles NNW of Nigal.	Hira Teja	Dg	69	6×9	BM	Do.
721	1·1 miles NNW of Nigal.	Abhai Rajji	Dg	71	11×6	BM	Brown sandstone with thin intercalated shales.
722	Do.	Mata Dhana Bisman.	Dg	77	8×6	BM	Do.
723	1·2 miles NNW of Nigal.	Basta Varjang	Dg,B	146	11×6	BM	Brown medium to coarse sandstone.
724	1·2 miles N. of Nigal.	Bhawanji Ramchhor.	Dg	69	11×5	BM	Do.
725	Do.	Nathu Bhana	Dg	66	5×7	BM	Sandstone with thin shales.
726	1·1 miles N. of Nigal.	Nathu Bhana	Dg,B	134	7×5	BM	Do.
727	1·05 mile N. of Nigal.	Gonda Vira	Dg,B	158	10×6	BM	Brown sandstones

See footnotes at end of table.

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1952)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Lower Bhuj	Top of mid. proj. SS. slab, N. side.	2·0	69·76	Apr. 17	I	..	Irrigates about 2 acres by one mote. Water has good taste. Water is sufficient for one mote
Do.	Top of mid. proj. SS. slab, E. side.	2·5	67·47	Apr. 20	I	..	Irrigates 2 acres by 2 motes. Water has good taste. Irrigates wheat and millet.
Do.	Do.	3·0	71·84	Do.	I	..	Irrigates 1½ acres by one mote. Water has good taste. Curbing 0-8 ft. Water insufficient for one mote.
Do.	Top of mid. proj. SS. slab, S. side.	3·0	70·22	Do.	I	..	Irrigates 2 acres by one mote. Water has good taste. Curbing 0-10 ft.
Do.	Top of mid. proj. SS. slab, W. side.	2·0	64·64	Do.	I	..	Irrigation by one mote. Water has good taste. Curbing 0-6 ft.
Do.	Top of mid. proj. SS. slab, N. side.	3·0	68·66	Do.	I	..	Irrigates 2 acres by one mote. Water has good taste.
Do.	Do.	2·0	66·30	Do.	I	..	Irrigates 2 acres by one mote. Water has good taste. Irrigates wheat and millet.
Do.	Top of mid. proj. SS. slab, E. side.	2·0	68·71	Do.	I	..	Irrigates 2 acres by one mote. Water has good taste. Water insufficient.
Do.	Top of mid. proj. SS. slab, S. side.	2·0	72·39	Do.	I	..	Irrigates 5 acres by one mote. Water has good taste. Irrigates wheat, millet, etc.
Do.	Do.	3·0	60·85	Do.	I	..	Irrigation by one mote. Dug 66 ft. and then one open boring 30 ft. deep.
Do.	Top of mid. proj. SS. slab, E. side.	3·0	61·58	Do.	I	..	Irrigates 2 acres by 2 motes. Water has brackish taste. Curbing 0-12 ft.
Do.	Do.	3·0	59·10	Apr. 25	Un	82	Abandoned at present.
Do	Do.	3·0	60·00	Do.	I	82	Irrigates about 2 acres by 2 motes. Water has brackish taste. Curbing 0-5 ft.
Do.	Do.	2·0	62·90	Do.	I	..	Irrigates 4 acres by 3 motes. Water has slightly brackish taste. Dug 68 ft. and then one open boring 90 ft. deep.

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type[1]	Depth (feet)	Dimensions (feet)	Method of lift[2]	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
728	1·0 mile N. of Nigal.	Dana Vasta .	Dg	69	10×5½	BM	Brown sandstones and shales.
729	0·95 mile N. of Nigal.	Karsan Vasta .	Dg	70	10×5½	BM	Do.
730	0·3 mile N. of Nigal.	Deka Teja Patel	Dg	73	6×7½	BM	Thin bedded sandstones and shales.
731	0·9 mile NNW of Nigal.	Lachhman Deko	Dg	71	7×5	BM	Brown sandstone
732	1·1 miles NNW of Nigal.	Karsan Teja .	Dg	74	10×6	BM	Thin sandstones and shales.
733	1·0 mile NNW of Nigal.	Sanga Vira Savania.	Dg	76	6×7	BM	Do.
734	1·0 mile NNW of Nigal.	Gonda Bana .	Dg, B	171	11×6	BM	Do.
735	0·9 mile NNW of Nigal.	Gopal Ganga .	Dg	72	8×5	BM	Brown sandstones
736	0·95 mile NNW of Nigal.	Vera Bana .	Dg	65½	5×7½	BM	Sandstones and sandy shales.
737	1·1 miles N. of Nigal.	Dana Bana .	Dg	68	7×8½	BM	Do.
738	1·1 miles N. of Nigal.	Dana Teja .	Dg	69	12×6	BM	Brown sandstones
739	1·2 miles NNW of Nigal.	Do.	Dg	69	12×6	BM	Do.
740	1·1 miles NNW of Nigal.	Mata Kara Warjan.	Dg	69	5×8½	BM	Do.
741	1·15 miles NNW of Nigal.	Gonda Vasta .	Dg	68	5½×7½	BM	Do.

See footnotes at end of table.

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 8	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1952)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Lower Bhuj.	Top of mid. proj. SS. slab, W. side.	2·0	61·40	Apr. 25	I	..	Irrigates 1½ acres by 2 motes. Water has brackish taste. Curbing 0-15 ft.
Do.	Do.	2·0	65·34	Do.	I	..	Irrigates 1½ acres by one mote. Water has good taste. Curbed 0-9 ft.
Do.	Top of mid. proj. SS. slab, E. side.	0	70·37	Do.	I	87	Irrigation by 2 motes. Water has good taste. Cultivate three crops a year. Curbing 0-3 ft.
Do.	Top of mid. proj. SS. slab, W. side.	2·0	68·70	Apr. 26	I	..	Irrigation by one mote. Water has good taste. Curbing 0-3 ft.
Do.	Do.	3·0	69·59	Do.	I	..	Irrigates about 2 acres by 2 motes. Water has good taste. Curbing 0-6 ft.
Do.	Top of mid. proj. SS. slab, E. side.	..	70·30	Do.	I	..	Irrigates 3 acres by one mote. Water has good taste. Curbing 0-9 ft.
Do.	Do.	3·0	67·98	Do.	I	..	Irrigation by one mote. Water has good taste. Curbing 0-6 ft.
Do.	Do.	2·0	67·59	Do.	I	84	Irrigation by one mote. Water has good taste. Curbing 0-7 ft.
Do.	Do.	3·0	62·39	Do.	I	..	Irrigation by one mote. Water has brackish taste. Curbing 0-9 ft.
Do.	Top of mid. proj. SS. slab, N. side.	..	61·72	Do.	I	..	Irrigates one acre by one mote. Curbing 0-4 ft.
Do.	Top of mid. proj. SS. slab, W. side.	2·0	65·08	Do.	I	85	Irrigation by 2 motes. Water has barckish taste. Curbing 0-7 ft.
Do	Do.	2·0	65·08	Do.	I	85	Irrigation by 2 motes. Water has brackish taste. Cultivates 3 crops a year. Curbing 0-7 ft.
Do.	Top of mid. proj. SS. slab, E. side.	2·0	66·56	Do.	I	..	Irrigates 4 acres by 2 motes. Water has good taste. Curbing 0-6 ft. Cultivates 3 crops.
Do.	Do.	..	65·82	Do.	I	..	Irrigation by one mote. Water has good taste. Curbing 0-6 ft. Irrigates one wheat and two millet crops.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
742	1·11 miles NNW of Nigal.	Vasa Dana	Dg	69	5×8	BM	Brown sandstones
743	1·4 miles N. of Nigal.	Vera Nathu	Dg,B	108	5×8	BM	Thin shales and sandstones.
744	1·25 miles N. of Nigal.	Saja Karsan Viri.	Dg,B	132	9×6	BM	Do.
745	1·25 miles NNE of Nigal.	Biaram Teja	Dg,B	104	6×8	BM	Sandstones and shales.
746	1·2 miles NNE of Nigal.	..	Dg	71	6×11	BM	Do.
747	1·25 miles NNE of Nigal.	Mata Gonda Ganga.	Dg,B	155	5×10	BM	Thin bedded shales and sandstones.
748	1·3 miles NE of Nigal.	Gonda Vasta	Dg	68	6×8	BM	Do.
749	1·4 miles NNE of Nigal.	Beka Nahu	Dg	78	6×7	BM	Do.
750	Do.	Rupa Teja	Dg	66	10×5	BM	Do.
751	1·3 miles N. of Nigal.	Bhopal Teja	Dg,B	182	11×5	BM	Thin bedded sandstones and shales.
752	1·4 miles N. of Nigal.	Kara Dhana	Dg	84	10×6	BM	Do.
753	Do.	Karsan Denkan Sega.	Dg,B	178	10×5	BM	Do.
754	1·2 miles N. of Nigal.	Kara Nathu	Dg,B	108	8×5	BM	Do.

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1952)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Lower Bhuj.	Top of mid. proj. SS. slab, N. side.	..	67·47	Apr. 26	I	85	Irrigation by two motes. Water has good taste. Curbing 0-10 ft.
Do.	Top of mid. proj. SS. slab, E. side.	3·0	76·42	Apr. 27	I	..	Irrigation by 2 motes. Water has good taste. Dug 83 ft. and then open bore 25 ft. deep.
Do.	Do.	2·0	65·72	Do.	I	..	Irrigates 4 acres by 2 motes. Dug 72 ft. and then one open boring 60 ft. deep.
Do.	Top of mid. proj. SS. slab, W. side.	2·0	69·40	Do.	I	86	Irrigates 4 acres by 2 motes. Water has good taste. Dug 74 ft. and then one open boring 30 ft. deep.
Do.	Top of mid. proj. SS. slab, N. side.	3·0	61·17	Do.	I	..	Irrigates 2 acres by one mote. Water has good taste. Curbing 0-7 ft.
Do.	Top of mid. proj. SS. slab, E. side.	..	67·42	Do.	I	86	Irrigates 6 acres by 3 motes. Water has slightly brackish taste. Dug 75 ft. then one open boring 80 ft. deep.
Do.	Do.	3·0	56·60	Do.	I	..	Irrigates 3 acres by 2 motes. Water has good taste. Curbing 0-7 ft.
Do.	Do.	2·0	69·30	Do.	I	..	Irrigates one acre by one mote. Water has good taste. Curbing 0-10 ft.
Do.	Do.	2·0	64·02	Do	I	..	Irrigation by one mote. Water has good taste.
Do.	Do.	2·0	69·08	Do.	I	..	Irrigates 3 acres by 2 motes. Water has good taste. Dug 72 ft. and then open boring 110 ft. deep. Curbing 0-16 ft.
Do.	Top of mid. proj. SS. slab, W. side.	..	70·89	Do.	I	..	Irrigates 4 acres by 2 motes. Working 8 hrs./day for 10 months a year. Water has good taste. Curbing 0-8 ft.
Do.	Do.	3·0	76·22	Do.	I	..	Irrigates 2 acres by 2 motes. Working 6 hrs./day for 10 months a year. Irrigates wheat and millet. Water has good taste.
Do.	Top of mid. proj. SS. slab, E. side.	3·0	69·75	Apr. 28	I	..	Irrigates 4 acres by 2 motes. Water has good taste. Dug 73 ft. and then one open boring 35 ft. deep.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type 1	Depth (feet)	Dimensions (feet)	Method of lift 2	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
755	1·2 miles N. of Nigal.	Karsan Ratta .	Dg	108	9×6	BM	Thin bedded sandstones and shales.
756	1·1 miles N. of Nigal.	Gokul Gonda .	Dg, B	118	8×5	BM	Do.
757	1·1 miles N. of Nigal.	Gopal Dana .	Dg	74	7×5	BM	Shales and yellow sandstone.
758	1·2 miles N. of Nigal.	Teja . .	Dg	78	10×5	BM	Sandstones and shales.
759	1·25 miles N. of Nigal.	Gopal Kara .	Dg	111	10×6	BM	Do.
760	1·1 miles N. of Nigal.	..	Dg	69	11×5	BM	Do.
761	0·9 mile N. of Nigal.	Dana Nara .	Dg	69	6×11	BM	Do.
762	0·85 mile N. of Nigal.	Hira Daya Gopal Karsan.	Dg, B	150	10×6	BM	Do.
763	0·65 mile N. of Nigal.	Deko Sava .	Dg, B	100	12×6	BM	Do.
764	0·7 mile N. of Nigal.	Hira Karsan .	Dg, B	127	10×6	BM	Do.
765	0·65 mile N. of Nigal.	Rawa Gonda .	Dg, B	134	12×7	BM	Do.
766	0·8 mile NNE of Nigal	Ranmalji Jadeja	Dg, B	147	7×5	BM	Do.
767	0·85 mile NNE of Nigal.	Rakha Kara .	Dg, B	136	5×7	BM	Do.

See footnotes at end of table.

DIX 14—*contd.*

Khedoi region, Anjar *taluk*, eastern Kutch —*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	Remarks
	Measuring Point		Depth to water (feet)	Date of measurement (1952)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Lower Bhuj.	Top of mid. proj. SS. slab, W. side.	2·0	62·39	Apr. 28	I	..	Irrigates 2 acres by one mote. Water has good taste. Dug 68 ft. and then one open boring 40 ft. deep.
Do.	Top of mid. proj. SS. slab, E. side.	..	66·71	Do.	I	..	Irrigates 2 acres by one mote. Dug 73 ft. and then one open boring 40 ft. deep. Curbing 0-7 ft.
Do.	Top of mid. proj. SS. slab, S. side.	2·0	69·95	Do.	I	..	Irrigates 2 acres by one mote. Water has good taste. Curbing 0-4 ft.
Do.	Top of mid. proj. SS. slab, E. side.	2·0	70·38	Do.	I	..	Irrigates 2 acres by one mote. Water has good taste. Curbing 0-5 ft.
Do.	Top of mid. proj. SS. slab, W. side.	3·0	73·82	Do.	I	..	Irrigates 3 acres by one mote. Dug 81 ft. and then one open boring 30 ft. deep.
Do.	Top of mid. proj. SS. slab, E. side.	3·0	61·22	Do.	I	..	Irrigation by 2 motes. Water has brackish taste. Curbing 0-8 ft.
Do.	Top of mid. proj. SS. slab, W. side.	0	64·69	Do.	I	86	Irrigates 4 acres by 2 motes. Water has good taste. Curbing 0-10 ft.
Do.	Top of mid. proj. SS. slab, E. side.	3·0	64·74	Do.	I	..	Irrigation by 2 motes. Water has good taste. Dug 70 ft. and then one open boring 80 ft. deep. Curbing 0-16 ft.
Do.	Do.	2·0	64·64	Apr. 30	I	85	Irrigates 4½ acres by one mote. Water has good taste. Dug 70 ft. and then open boring 30 ft. deep.
Do.	Do.	..	55·89	Do.	I	..	Irrigates 3 acres by 2 motes. Water has brackish taste. Dug 62 ft. and then one open boring 65 ft. deep.
Do.	Top of mid. proj. SS. slab, W. side.	1·0	59·13	Do.	I	..	Irrigates 3 acres by one moto. Water has brackish taste. Dug 64 ft. and then one open boring 70 ft. deep.
Do.	Top of mid. proj. SS. slab, N. side.	3·0	53·44	Do.	I	..	Irrigates 2 acres by one moto. Water has brackish taste. Dug 57 ft. and then one open bore 90 ft. deep.
Do.	Top of mid. proj. SS. slab, E. side.	4·0	56·85	Do.	I	..	Irrigates 2 acres by 2 motes. Water has good taste. Dug 66 ft. and then one open boring 70 ft. deep.

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type [1]	Depth (feet)	Dimensions (feet)	Method of lift [2]	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
768	0·9 mile N. of Nigal.	Karsan Teja	Dg	69	5×11	BM	Sandstones and shales.
769	1·0 mile NNE of Nigal.	Mata Dhama	Dg	67	11×5	BM	Do.
770	0·9 mile NNE of Nigal.	Deka Vira	Dg	69	6×9	BM	Do.
771	1·1 miles NNE of Nigal.	Masta Vira	Dg	71	6×7	BM	Do.
772	1·1 miles NNE of Nigal.	Nathu Samath	Dg, B	83	6×11	BM	Do.
773	1·0 mile NNE of Nigal.	..	Dg	63	6×12	BM	Do.
774	1·0 mile NNE of Nigal.	Rawa Teja	Dg, B	129	6×11	BM	Do.
775	1·1 miles NNE of Nigal.	Karsan Waste	Dg	59	5×7	BM	Do.
776	1·0 mile NNE of Nigal.	Gonda Bhoja	Dg, B	109	11×6	BM	Do.
777	1·2 miles NNE of Nigal.	Mata Gopal Ganga.	Dg, B	107	6×11	BM	Do.
778	1·1 miles NNE of Nigal.	Mata Bisram Ganga.	Dg, B	108	6×10	BM	Do.
779	1·3 miles NNE of Nigal.	Karsan Gonda	Dg	59	8×6	BM	Do.

See footnotes at end of table.

Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1952)	3		
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Lower Bhuj.	Top of mid. proj. SS. slab, E. side	..	65·04	Apr. 30	I	..	Irrigates 4 acres by 2 motes. Water has good taste. Curbing 0-12 ft. Irrigates wheat and millet, etc.
Do.	Top of mid. proj. SS. slab, W. side.	..	64·34	Do.	I	..	Irrigates 2 acres by 2 motes. Water has good taste. Irrigates wheat and millet, etc.
Do.	Top of mid. proj. SS. slab, N. side.	3·0	63·09	Do.	I	..	Irrigates 2 acres by one mote. Water has good taste. Curbing 0-8 ft.
Do.	Top of mid. proj. SS. slab, E. side.	3·0	64·49	Do.	I	..	Irrigation by one mote. Water has good taste. Curbing 0-14 ft.
Do.	Do.	3·0	57·79	Do.	I	86	Irrigates 4 acres by 2 motes. Water has good taste. Curbing 0-12 ft. Dug. 63 ft. and one open boring 20 ft. deep.
Do.	Do.	0	52·43	Do.	I	..	Irrigation by one mote. Water has brackish taste. Curbing 0-11 ft. Irrigates only one millet crop.
Do.	Do.	3·0	65·00	Do.	I	..	Irrigation by one mote. Water has brackish taste. Dug 69 ft. and then one open boring 60 ft. deep. Curbing 0-14 ft.
Do.	Do.	2·0	58·77	Do.	I	..	Irrigates 4 acres by 2 motes. Water has good taste. Curbing 0-12 ft.
Do.	Do.	..	85·87	Do.	I	..	Irrigation by 3 mote wells. Water has good taste. Curbing 0-14 ft. Dug 69 ft. and then one open boring 40 ft. deep.
Do.	Do.	2·0	49·72	Do.	I	..	Irrigates 2 acres by one mote. Water has good taste. Dug 57 ft. and then one open boring 50 ft. deep.
Do.	Do.	2·0	58·43	Do.	I	..	Irrigation by 2 motes. Water has good taste. Dug 63 ft. and then one open boring 40 ft. deep.
Do.	Do.	1·0	53·98	May 9	I	..	Irrigates 2 acres by one mote. Water has brackish taste. Curbing 0-4 ft.

APPEN

Hydrologic data for wells in the Anjar-

Well No.	Location	Owner	Type[1]	Depth (feet)	Dimensions (feet)	Method of lift[2]	Nature of water-bearing material
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
780	1·4 miles NNE of Nigal.	Bhima Mala .	Dg	59	8×5	BM	Sandstones and shales.
781	1·2 miles NNE of Nigal.	..	Dg	54	6×8	BM	Do.
782	1·4 miles NNE of Nigal.	Deva Megar .	Dg, B	147	8×7	BM	Do.
783	Do.	Karsan Ganga .	Dg	59	5×7	BM	Do.
784	1·5 miles NNE of Nigal.	Bhura Teja .	Dg	64	6×11	BM	Do.
785	1·6 miles NNE of Nigal.	Mata Seva Puja	Dg	72	10×6	BM	Do.
786	1·4 miles NNE of Nigal.	..	Dg	54	6×8	BM	Do.
787	1·5 miles NNE of Nigal.	..	Dg	60	7×9	BM	Do.
788	0·85 mile SSE of Nigal.	Bijal Teja .	Dg	50	6×7	BM	Do.
789	0·7 mile S. of Nigal	Jain Bijal Nagdan.	Dg, B	61	6×8	BM	Do.
790	0·75 mile S. of Nigal	Jain Dana Hira.	Dg	50	7×9	BM	Do.
791	0·9 mile SSW of Nigal.	Kara Jiwan .	Dg	63	5×7	BM	Do.
792	0·5 mile SW of Nigal.	Nana Nirba .	Dg	57	7×9	BM	Sandstone with a trap sill (?) at the bottom.
793	0·7 mile SW of Nigal.	Ram Sur Kara .	Dg	41	6×9	BM	Sandstones and shales.
794	1·0 mile SW of Nigal.	Makwara Kara Rana.	Dg	40	5×7	BM	Sandstone and thin shales.
795	1·2 miles NE of Nigal.	Nagu Khengar .	Dg	34·9	6×8	BM	Do.
706	1·4 miles NE of Nigal.	Kachara Teja .	Dg, B	90	6×8	BM	Ferruginous sandstones.

---

[1] B—bored; Dr—drilled; Dg—dug.

[2] BM—bullocks and morte; HC—horizontal centrifugal pump; WW—water wheel.

[3] D—domestic: I—irrigation; S—stock; P—public; Un—unused or abandoned.

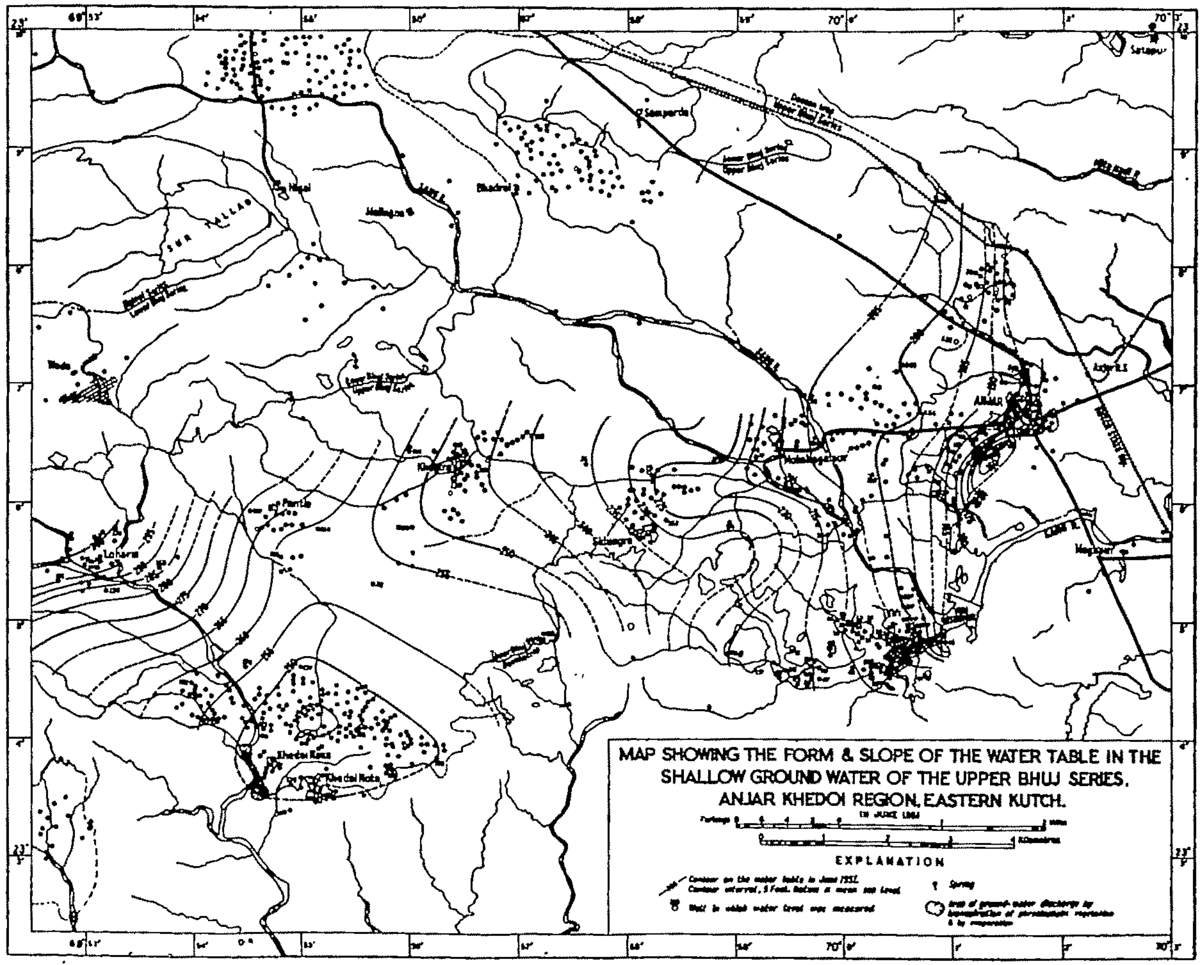
Khedoi region, Anjar *taluk*, eastern Kutch—*contd.*

Geologic horizon	Water Level				Use 3	Temperature (F°)	REMARKS
	Measuring Point		Depth to water (feet)	Date of measurement (1952)			
	Description	Above land surface (feet)					
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
Lower Bhuj.	Top of mid. proj. SS. slab, W. side.	3·0	53·78	May 9	I	..	Irrigation by one mote. Water has good taste. Curbing 0-13 ft.
Do.	Top of mid. proj. SS. slab, E. side.	2·0	42·44	Do.	I	..	Irrigation by one mote. Water has brackish taste. Curbing 0-18 ft.
Do.	Top of mid. proj. SS. slab, W. side.	3·0	51·88	Do.	I	..	Irrigation by 2 motes. Water has brackish taste. Dug 57 ft. and then open boring 90 ft. deep.
Do.	Top of mid. proj. SS. slab, E. side.	3·0	56·80	Do.	I	..	Irrigation by one mote. Water has good taste. Curbing 0-6 ft.
Do.	Do.	3·0	59·29	Do.	I	..	Irrigation by one mote. Water has good taste. Curbing 0-10 ft.
Do.	Do.	2·0	68·27	Do.	I	86	Irrigates 2 acres by 2 motes. Water has good taste. Curbing 0-7 ft. Irrigates three crops.
Do.	Corner proj. SS. block, W. side.	3·0	49·79	Do.	I	..	Irrigation seasonal by one mote. Curbing 0-8 ft.
Do.	Top of mid. proj. SS. slab, W. side.	..	51·42	Do.	Un	..	Abandoned well. Curbing 0-6 ft.
Do.	Do.	3·0	44·65	May 10	I	..	Irrigates 2 acres by one mote. Water has good taste. Curbing 0-6 ft.
Do.	Top of mid. proj. SS. slab, E. side.	3·0	41·36	Do.	I	..	Irrigates 4 acres by 2 motes. Water has brackish taste. Dug 45 ft. and then open boring 16 feet deep.
Do.	Do.	..	46·42	Do.	I	..	Irrigation by one mote. Water has good taste. Curbing 0-12 ft.
Do.	Top of mid. proj. SS. slab, N. side.	..	59·58	Do.	I	...	Irrigation by one mote. Water has good taste. Curbing 0-7 ft.
Do.	Top of mid. proj. SS. slab, S. side.	..	50·57	Do.	I	..	Irrigates 2 acres by one mote. Well has insufficient water.
Do.	Top of mid. proj. SS. slab, E. side.	3·0	33·92	Do.	I	..	Irrigates 2 acres by one mote. Water has good taste. Curbing 0-5 ft.
Do.	Top of mid. proj. SS.	..	35·79	Do.	I	..	Irrigation by one mote. Water has good taste. Irrigates wheat and millet.
Do.	Top of mid. proj. SS. slab, W. side.	3·0	34·9	Do.	I	..	Irrigates 4 acres by 2 motes. Water has good taste. Curbing 0-18 ft.
Do.	Top of mid. proj. SS. slab, E. side.	3·0	35·23	Do.	I	..	Irrigation by 2 motes. Water has good taste. Curbing 0-7 ft. Dug 40 ft. then one boring 50 ft. deep.

MGIPC—S5—6 GSI/55—17-12-59—1,030.

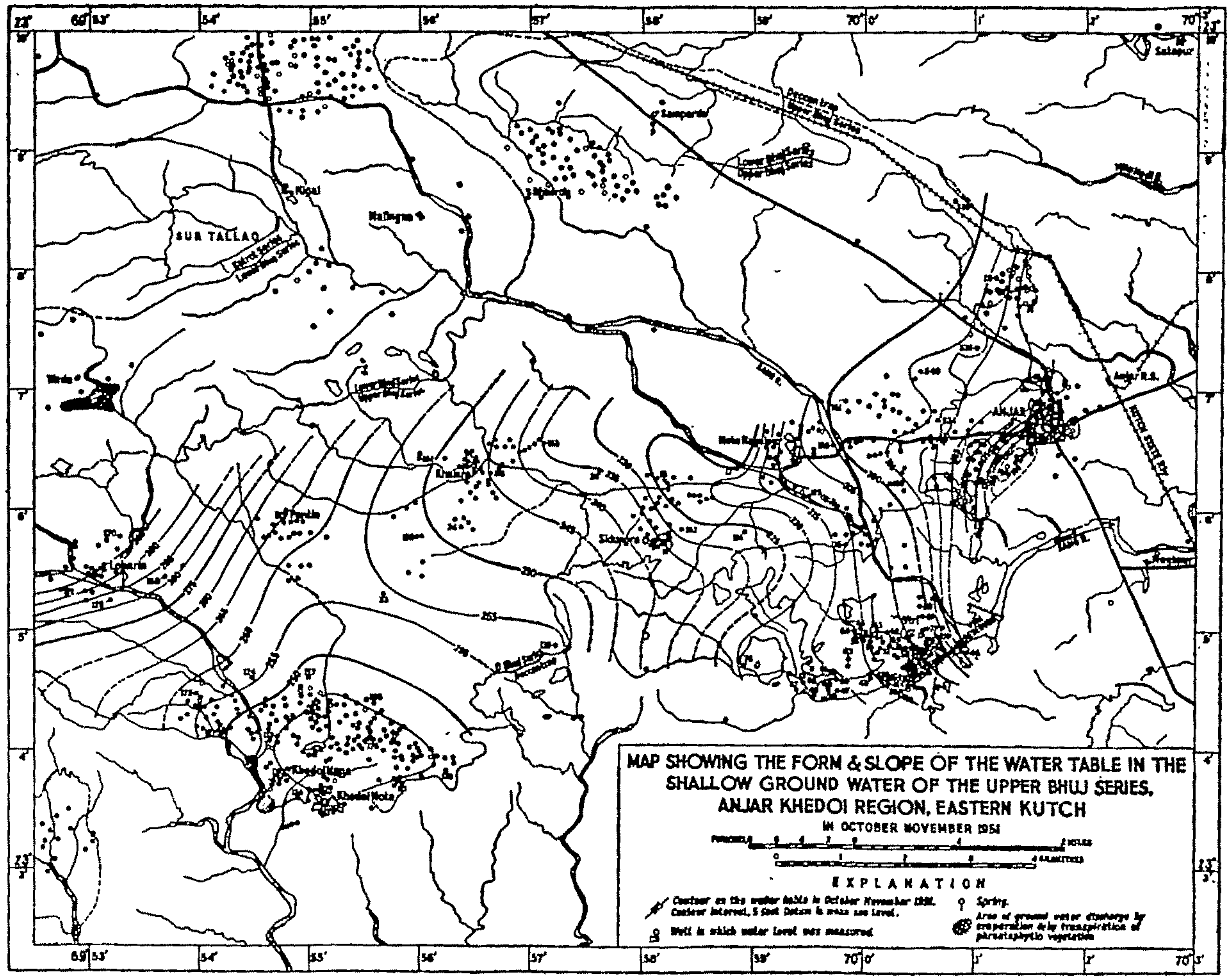
GEOLOGICAL SURVEY OF INDIA

Bull. Ser. B, No. 9, Pl. 2



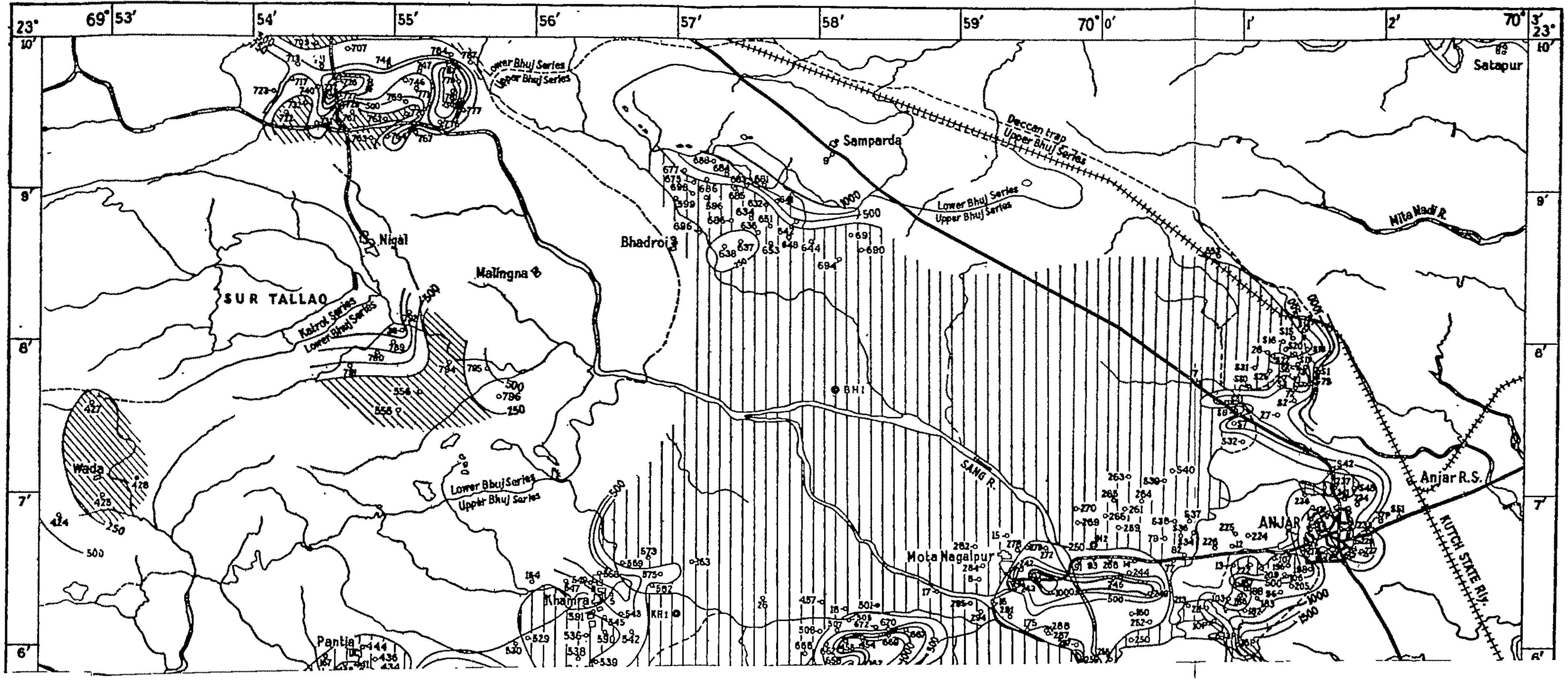
MAP SHOWING THE FORM & SLOPE OF THE WATER TABLE IN THE SHALLOW GROUND WATER OF THE UPPER BHUJ SERIES. ANJAR KHEDOI REGION, EASTERN KUTCH.

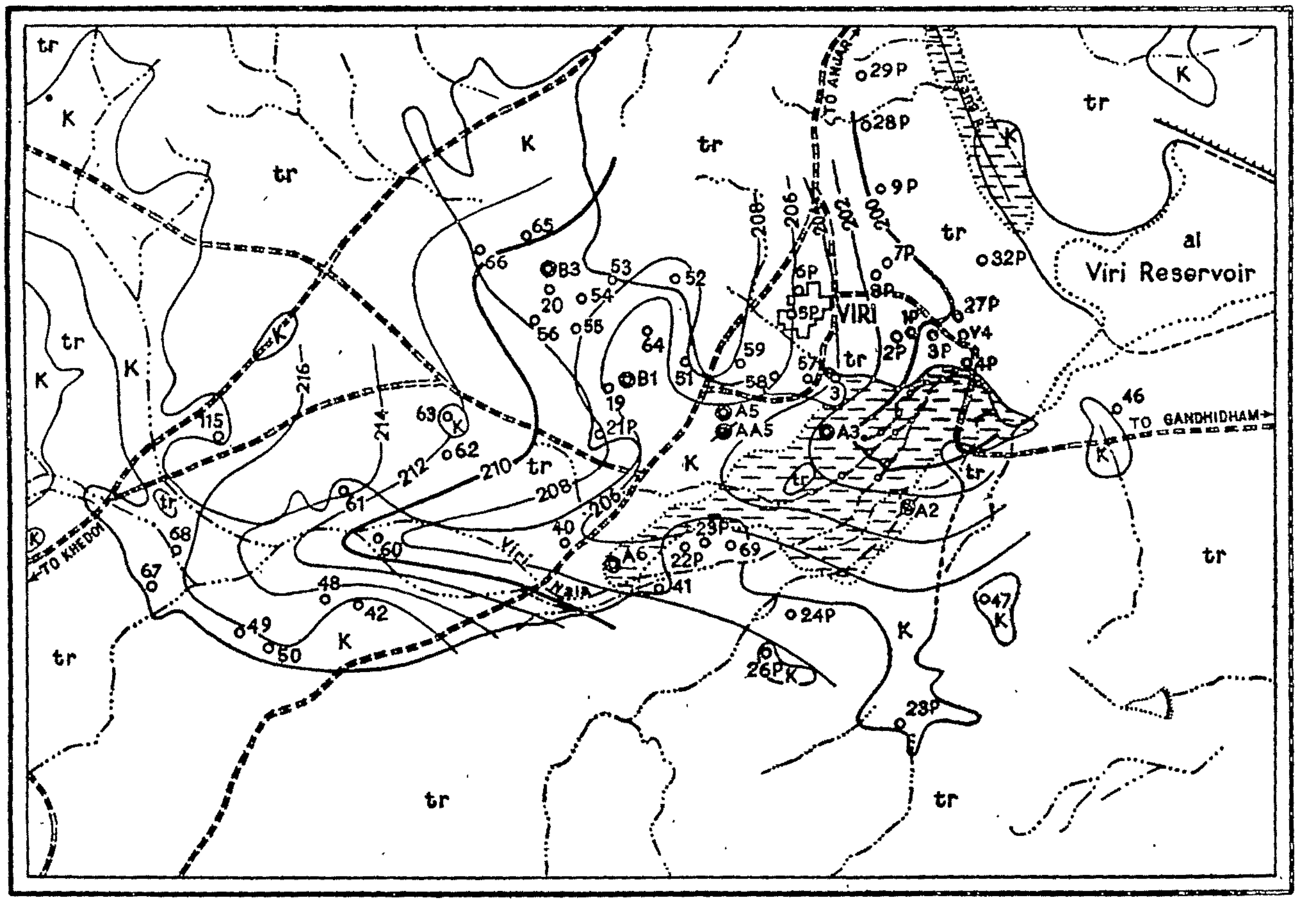
G. S. I. Calcutta



MAP SHOWING THE FORM & SLOPE OF THE WATER TABLE IN THE SHALLOW GROUND WATER OF THE UPPER BHUJ SERIES, ANJAR KHEDOI REGION, EASTERN KUTCH
IN OCTOBER NOVEMBER 1951

MILES
KILOMETRES
EXPLANATION
Contour on the water table in October November 1951. Contour interval, 5 feet Datum is mean sea level.
Well in which water level was measured.
Spring.
Area of ground water discharge by evaporation &/by transpiration of phreatophytic vegetation
ANJAR
Anjar R.S.
KUTCH STATE Rly.
Salapur
SUR TALLAO
Khedoi Nana
Khedoi Mota
Wirda
23° 10'
23° 3'
69° 53'
54'
55'
56'
57'
58'
59'
70° 0'
1'
2'
70° 3'


23°
69° 53′
54′
55′
56′
57′
58′
59′
70° 0′
1′
2′
70° 3′
10′
9′
8′
7′
6′
Satapur
Nita Nadi R.
Deccan trap
Upper Bhuj Series
Lower Bhuj Series
Upper Bhuj Series
Samparda
Bhadroi
Malingna
Nigal
SUR TALLAO
Katrol Series
Lower Bhuj Series
BH1
SANG R.
Wada
Lower Bhuj Series
Upper Bhuj Series
Mota Nagalpur
ANJAR
Anjar R.S.
KUTCH STATE Rly.
Khamra
KH1
Pantia
500
1000
250



MAP OF THE VIRI AREA, ANJAR-KHEDOI REGION, EASTERN KUTCH

SHOWING THE FORM & SLOPE OF THE WATER TABLE
IN THE SHALLOW GROUND WATER OF THE UPPER BHUJ SERIES.
JUNE 1951

SCALE 0 — 1 MILE
0 — 1 KM

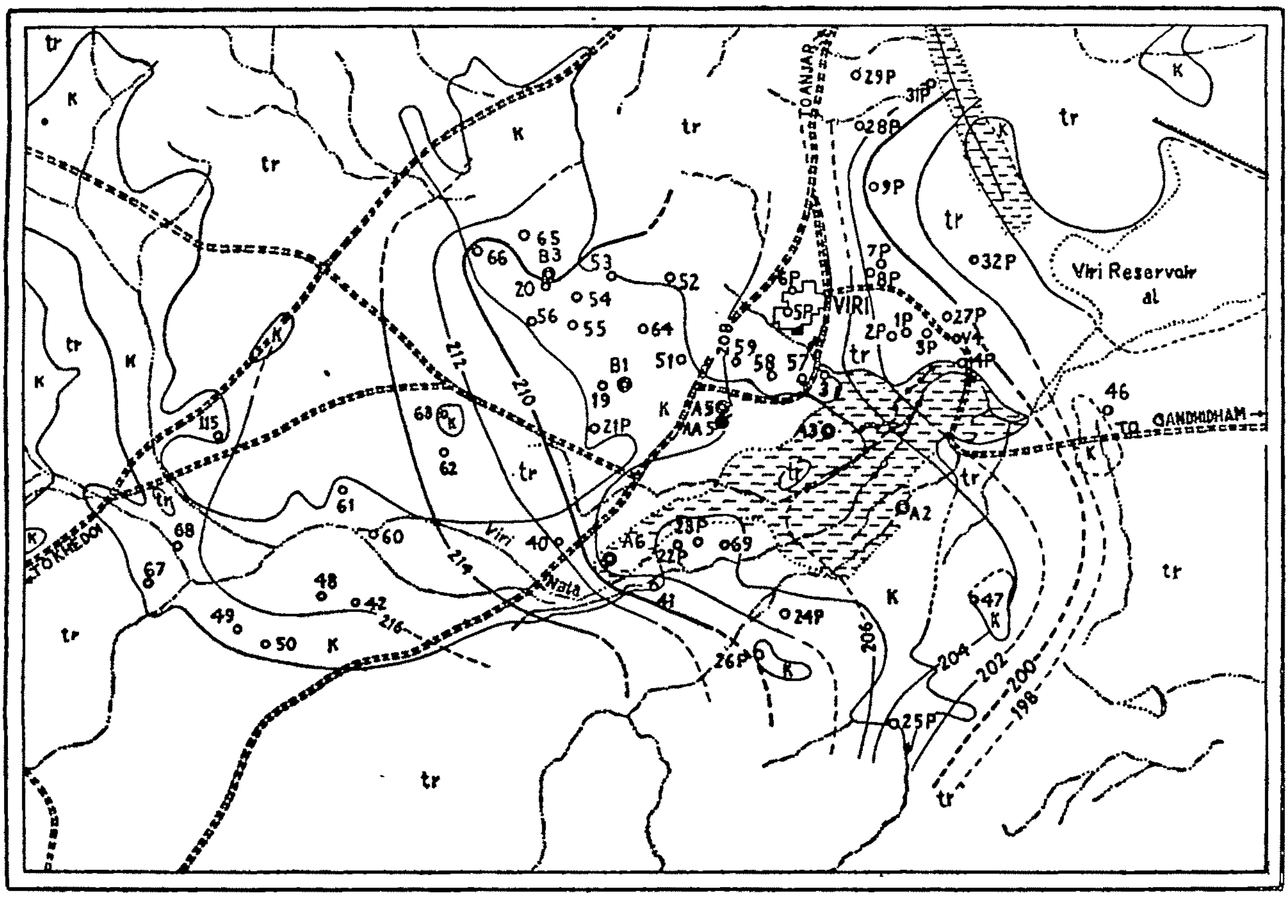
EXPLANATION

216 *Contour on the water table in June 1951. Contour Interval, 2 Feet. Datum is mean sea level.*

Area of ground water discharge by evaporation, transpiration & spring flow.

al	*Alluvium*
tr	*Deccan trap*
K	*Upper Bhuj series*
o 3	*Well in which water level was measured*
●A5	*Tube well*
ØA2	*Abandoned tube well*
o—	*Spring*

G. S. I., Calcutta.



MAP OF THE VIRI AREA, ANJAR-KHEDOI REGION, EASTERN KUTCH

SHOWING THE FORM & SLOPE OF THE WATER TABLE
IN THE SHALLOW GROUND WATER OF THE UPPER BHUJ SERIES

OCTOBER & NOVEMBER 1951

SCALE, 0 1 MILE.

0 1 KM

EXPLANATION

-216- *Contour on the water table in October & November 1951. Contour interval, 2 Feet. Datum is mean sea level.*

▨ *Area of ground water discharge by evaporation, transpiration & spring flow.*

al *Alluvium*

tr *Deccan trap*

K *Upper Bhuj series*

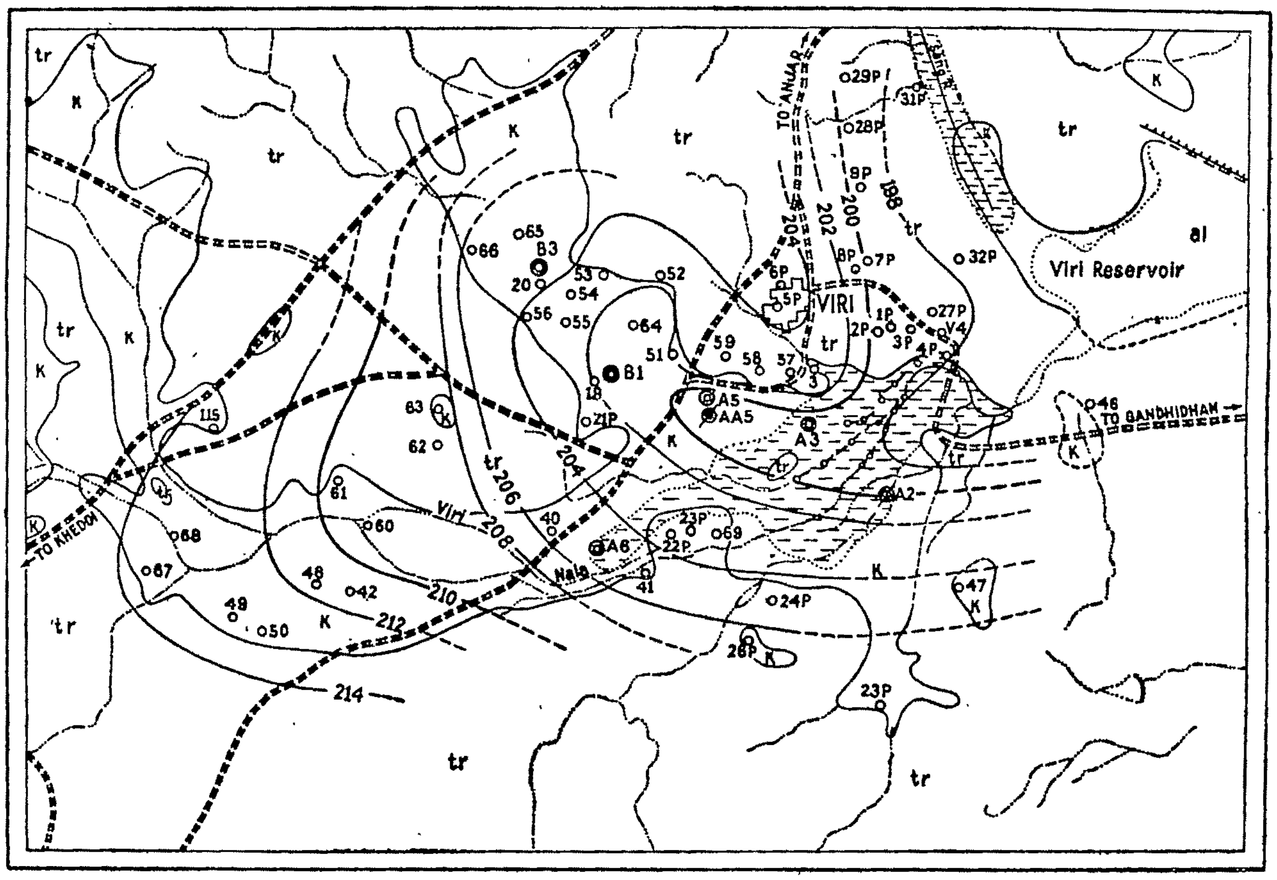
o3 *Well in which water level was measured*

●A5 *Tube well*

⊘A2 *Abandoned tube well*

o— *Spring*

G. S. I., Calcutta.



MAP OF THE VIRI AREA, ANJAR-KHEDOI REGION, EASTERN KUTCH

SHOWING THE FORM & SLOPE OF THE WATER TABLE
IN THE SHALLOW GROUND WATER OF THE UPPER BHUJ SERIES

MAY 1952

SCALE 0 — 1 MILE

0 — 1 KM

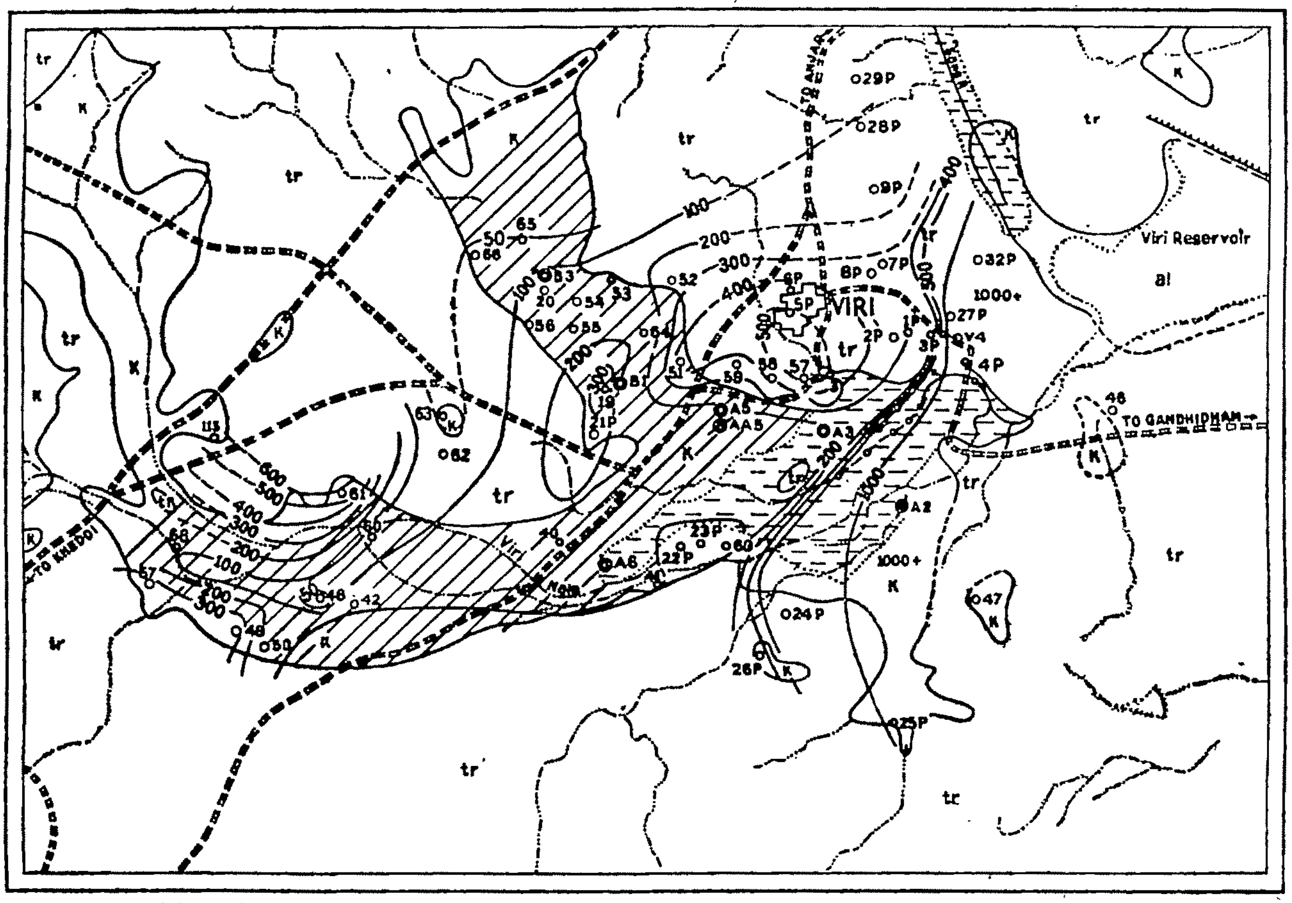
EXPLANATION

-216- *Contour on the water table in May 1952. Contour interval, 2 Feet. Datum is mean sea level.*

▨ *Area of ground water discharge by evaporation, transpiration & spring flow.*

al	*Alluvium*
tr	*Deccan trap*
K	*Upper Bhuj series*
o3	*Well in which water level was measured*
●A5	*Tube well.*
A2	*Abandoned tube well*
o—	*Spring*

G. S. I., Calcutta.



MAP OF THE VIRI AREA, ANJAR-KHEDOI REGION, EASTERN KUTCH
SHOWING THE DISTRIBUTING OF CHLORIDES.
IN THE SHALLOW GROUND WATER OF THE UPPER BHUJ SERIES.
JUNE 1951

SCALE 0 — 1 MILE

0 — 1 KM

EXPLANATION

▨ *Area in which the shallow ground water of the Upper Bhuj series generally contains less than 800 parts per million of chlorides. Water of good chemical quality & generally suitable for public water supply & for irrigation.*

500 *Isochlor (line of equal chloride content in the shallow ground water, in parts per million). Samples taken in June 1951.*

Area of ground water discharge by evaporation, transpiration and spring flow.

al	*Alluvium*
tr	*Deccan trap*
K	*Upper Bhuj series*
o3	*Well sampled for chloride analysis*
●A5	*Tube well*
A2	*Abandoned tube well*
o—	*Spring*

G. S. I., Calcutta.

INTRODUCTION

Following the conclusion of an agreement between the Governments of India and the United States, dated May 31, 1952, with a supplement dated April 28, 1953, drilling of wells for the States of PEPSU, Punjab, Uttar Pradesh, and Bihar was undertaken for production of irrigation water. As a part of this agreement, known generally as Operational Agreement No. 6, a contract was entered into between a French drilling concern and the Punjab State Government to drill about 175 wells in two areas in the Punjab.

In one of these areas, known as the Shahabad-Pipli-Ladwa area, 125 wells were scheduled for construction. Because of the availability of this area to major lanes of transport, it was decided by the officials of the Geological Survey of India to make on a reconnaissance basis, a survey of data accruing from the drilling programme, to obtain data from sources other than the drilling of the tubewells, and finally to prepare a report showing the utility of these composite data in an appraisal of groundwater resources and geological conditions within the area included in the irrigation tubewell programme.

Although drilling under Operational Agreement No. 6 is currently being carried on in other places, investigational work by the Geological Survey of India, as outlined above, is not being undertaken on an equally large scale. Rather, the emphasis is being placed at present on investigation of limited scope in selected localities, such as the Shahabad-Pipli-Ladwa area, so that State agencies involved may know the value of these investigations in obtaining information that would otherwise be lost.

The collection of data and all field observations were carried out from January 22 to February 14, 1955. The Officers assigned for the work were A. B. Biswas, (author), and Y. S. R. L. Narasimham, N. Kameswaran, and B. N. Niyogi, Well Logging Operators, all of the Geological Survey of India. The chemical analyses of water samples were carried out by S. R. Maitra, Assistant Chemist, Geological Survey of India.

Location and general features

The Shahabad-Pipli-Ladwa area (inset, Pl. 1) is in the Thanesar *tahsil* of Karnal district of the Punjab State. It lies between latitudes 29° 53′ and 30° 10′ and longitudes 76° 51′ 30″ and 77° 03′ 30″ in the north-eastern part of the Karnal district, making up an area of about 78 square miles. It is included in parts of topo-sheet Nos. 53 B/16, 53 F/14, 53 G/1 and 53 C/13. The triangular area is about 12 miles long from north to south and 10 miles from east to west along its southern boundary. The area has been named from the three villages located respectively at each apex of the triangular area. Ambala is only 15 miles from the northern end of the area, and Karnal, the District Headquarters, is about 30 miles south of its southern end. Delhi is about 70 miles further south.

The area is well connected by roads and railway. The Grand Trunk Road, along the western edge of the area, is the main arterial line of communication. Other roads run east from Pipli to and beyond Ladwa and from Ladwa to Shahabad. The former, like the Grand Trunk Road, is an all-weather metalled highway. The latter, however, is a dirt track negotiable only during the dry season.

Kurukshetra, the rail head nearest the southern part, is only 3½ miles, west of Pipli. To the north, the Kharinda railway station lies just west of Shahabad ; both railway stations are on the main broad gauge line between Delhi and Ambala. This line, of the Northern Railway, runs parallel to and on the west of the Grand Trunk Road.

Throughout the area, the villages are more or less well connected by cart tracks which are motorable, at least by jeep, during all but the wet season, at which time they are impassable except by bullock cart.

Land used for cultivation in the area is quite fertile and supports good crops; wheat, gram, oil seeds, and sugar-cane are the chief crops which are grown in the area. Besides, various kinds of vegetables are also produced. A type of grass used as fodder for cattle grows luxuriantly in a tract south of Machrauli.

Scope and nature of the investigation

The investigation was, to a large extent, an experiment designed to determine the extent to which the data obtained from a large scale tubewell drilling programme may be used to elaborate on other information for an area. The result is a reconnaissance report of enhanced utility. Such an investigation may yield excellent information on the subsurface geology, based on the data available as a result of drilling the tubewells.

The objective of the investigation was to determine the nature and occurrence of the groundwater resources in the area down to the depths drilled and to report on the geohydrologic relationships so far as feasible, considering the brief period covered by the investigation.

The field investigation accomplished the following :—

Open wells canvassed	84
Tubewells for which electrical logs were run with the Widco logger	4
Open wells sampled for partial chemical analysis . .	37
Open wells for which at least one water-level measurement was taken	84
Tubewells sampled for chemical analysis	2
Tubewells for which at least one water-level measurement was taken	4
Tubewells for which logs (strata charts) were obtained	58
Tubewells for which locations in field were actually determined by bearing intersection	4
Tubewells for which pumping data were obtained . . .	41

Based on standard procedures adopted by the Geological Survey of India certain data are obtained from a well when visited by field personnel. The process of proceeding from well to well and recording data is known as a well canvass. During this canvass, the data obtained are as follows : Location, owner's name, whether dug or drilled, depth and diameter, use, yield, principal water yielding zone tapped, and, if a tubewell, an account of the type of well, kind of pump, location of strainers or perforated section. Also, a water-level measurement is taken with reference to a well defined measuring point, as well as a water sample for chemical analysis.

Only in exceptional cases can all the foregoing information be collected for all the wells canvassed. In the case of the tubewells drilled in area, it was not possible to obtain a water-level measurement after installation of the pump. Also, because the pumps in the area have not yet been energised, it was not possible to collect water samples from any of the tubewells. For this reason, many of the tubewells were not visited by Geological Survey of India officers. The wells are plotted on Plate 1 as scaled from Punjab State maps showing their approximate locations. Also plotted on this plate are open wells canvassed in the field, as are the main and connecting roads and important towns.

A word should be included here describing the numbering system used in designating open wells in this report. In both the text and on the maps these wells have been assigned a number based on their position on the one inch to the mile topographic maps. For instance, well 53 B/16-3B2 is on topographic map 53 B/16 and is the second well to be plotted in the section on the map whose vertical coordinate is 3 and horizontal coordinate B. On the maps included in the report, the prefix indicating the topographic map numbers have been deleted to save space. The deep wells have been assigned their State designation without regard to where their plotted location falls within the map.

Acknowledgments

The work was carried out by the author under the general supervision of Mr. G.C. Chaterji, Superintending Geologist, Groundwater Exploration Section, Geological Survey of India. General advice and counsel was provided by Mr. A.A. Garrett, U.S. Geological Survey, on deputation to the Geological Survey of India.

The author is grateful to the Punjab State officials, whose assistance materially increased the effectiveness of this investigation. Mr. R.K. Sabharwal, Executive Engineer, Tubewell Division 1, Delhi, and Messrs. I.L. Mair and Y.R. Karla, Sub-divisional Officer, Punjab, P.W.D. deserve special thanks.

The author's gratitude is also extended to officials of the French Group of Drilling Companies for their sincere co-operation and help during the electrical logging of the deep boreholes.

Climate

The climate of the area is of the most pronounced continental character. Due to its remoteness from the sea, extreme summer heat alternates with nearly freezing winter temperatures. In December and January the night temperatures are the lowest of the year ; the winter months are very pleasant and invigorating. The mean temperature increases from February into May and by the end of March or the beginning of April the hot season is fairly well established. Strong dust-raising windstorms occur during part of the summer season, adding further to the discomforts. The mean monthly temperature data for two stations at Karnal and Ambala are given in Table 1.

TABLE 1.—*Mean monthly Temperature data for two stations near the Shahabad-Pipli-Ladwa area (in Fahrenheit).*

Month	Station at Karnal*		Station at Ambala†	
	Maximum	Minimum	Maximum	Minimum
January . . .	69·0	44·1	69·1	43·4
February . . .	74·5	49·1	73·1	47·8
March	84·4	56·9	84·3	56·5
April	96·5	66·6	96·4	66·4
May	104·3	76·6	103·9	75·8
June	102·9	81·1	103·6	80·7
July	94·5	78·1	95·5	79·1
August . . .	91·7	77·9	93·2	78·0
September . . .	92·4	74·5	94·0	73·9
October . . .	91·2	62·7	91·8	62·1
November . . .	81·9	51·0	82·1	49·9
December . . .	73·4	44·4	72·3	43·8

Punjab has in normal years two well defined rainy seasons. During the first, the period of the north-east monsoon between the end of December and the end of February or the middle of March, about 2·5 inches of rain can be expected. During the second, the period of the south-west monsoon from the end of June to the middle or end of September, about 21 inches of rain can be expected. For the 78 sq. mile area this means a total of about 10,400 acre-ft. of water during the winter monsoon and about 87,500 acre-ft. during the summer monsoon. Table 2 shows the yearly distribution of rainfall at two stations, the nearest available to the Shahabad-Pipli-Ladwa area.

---

* Based on monthly mean balance for five years from 1950-54, kindly supplied by the Director, Regional Meteorological Centre, New Delhi.

† Monthly normals based on data from 1896 to 1940.

TABLE 2.—*Mean monthly rainfall for two stations near the Shahabad-Pipli-Ladwa area (in inches).*

Month	Station at Karnal	Station at Thanesar	Average
October	0·51	0·50	0·50
November	0·16	0·11	0·13
December	0·44	0·44	0·44
January	1·27	1·11	1·19
February	1·19	1·24	1·22
March	0.60	0·66	0·63
April	0·47	0·51	0·49
May	0·48	0·34	0·41
June	2·39	2·21	2·30
July	8·57	7·40	7·98
August	7·33	6·02	6·68
September	5·28	5·07	5·17
Total	28·69	25·61	27·14

Based on the rainfall records for the two stations, at Karnal and Thanesar, respectively, the average annual rainfall in the southern part of the area is about 27 inches. For the Punjab as a whole, rainfall is greatest in the northern part because of the proximity of mountainous areas, and decreases materially to the south and west. For instance, at Ambala the mean annual rainfall, based on a 60-year record is 32·97 inches.

Table 3 shows the annual rainfall data for the stations at Karnal and Thanesar for the period of record.

TABLE 3.—*Annual rainfall for two stations near the Shahabad-Pipli-Ladwa area, for the period 1900-50 (in inches).*

Year	Karnal	Thanesar
1900	46·18	18·15
1901	25·25	25·58
1902	32·50	18·58
1903	20·47	29·74
1904	33·63	28·53
1905	22·42	15·38
1906	30·51	29·03
1907	20·82	24·05
1908	37·65	19·19
1909	36·94	25·50
1910	30·19	26·13
1911	30·42	23·73
1912	28·66	27·93
1913	27·05	26·96
1914	36·15	40·98
1915	31·06	33·12
1916	35·19	29·48
1917	35·49	36·62
1918	14·02	12·98
1919	27·36	28·05
1920	15·93	14·32
1921	24·24	18·94
1922	31·88	28·77
1923	32·89	27·73
1924	37·13	35·36

TABLE 3.—*Annual rainfall, etc.*—contd.

Year	Karnal	Thanesar
1925	40·31	25·46
1926	25·47	16·42
1927	26·67	21·75
1928	21·96	23·10
1929	13·94	15·30
1930	17·56	18·05
1931	29·20	17·31
1932	32·75	27·09
1933	38·72	32·82
1934	34·23	18·62
1935	47·37	30·72
1936	35·09	29·29
1937	25·97	34·68
1938	14·80	16·01
1939	15·30	17·95
1940	16·55	17·57
1941	21·75	14·05
1942	41·39	49·25
1943	23·04	18·94
1944	27·38	19·59
1945	29·24	20·63
1946	18·86	19·75
1947	29·01	35·92
1948	34·15	20·10
1949	26·21	29·07
1950	32·10	41·99

These data are also shown graphically on Plate 2, fig. 1. The irregularities in precipitation from year to year are clearly shown. A slight tendency for cyclic conditions to occur is shown, particularly for the record at Karnal, the southernmost station of the two.

The effect of year-to-year carry-over of either excess or deficient rainfall can be studied to better advantage by accumulating the year-to-year departure from the arithmetic average, and plotting these against the years of record. These cumulative departures present a better picture of trends towards possible cyclic conditions (Plate 2b). From the nature of the data plotted temporary reversals in trend are to be expected. The slope of the graph for any portion of the record determines whether a period of below or above normal rainfall exists. For instance, the period from 1900 to about 1908 represents a time of below normal rainfall, with a persistent reversal for the 6-year period 1911-17. Another period of below normal rainfall occurred from 1925 to 1931.

There are also other methods of presenting rainfall data on an intensity frequency or depth frequency basis for extrapolating trends into the future. However, an analysis of the rainfall records on this basis is beyond the scope of this paper.

Table 4 shows the generalised rainfall conditions at the two stations for which data are considered in this report.

TABLE 4.—*Summarised rainfall conditions for stations at Karnal and Thanesar, Punjab, based on the 51-year record 1900-50.*

	Karnal	Thanesar
	(in inches)	
Mean annual	28·69	25·61
Maximum annual	47·35 (1935)	48·15 (1900)
Excess over mean	18·68	22·54
Minimum annual	13·94 (1929)	12·98 (1918)
Deficiency	14·75	12·63
Number of years in which rainfall was less than the mean.	24	27
Number of years in which rainfall was less than half the mean.	2	

Wind data available for two stations at Karnal and Ambala indicate that during greater part of the year wind blows from N. W. East and S. E. winds also blow during most part of the year but these directions appear to be more frequent during April-September. North wind blows generally during November-February.

Topography and Drainage

The area forms a part of the widespread Indo-Gangetic Plain and is more or less flat. The elevation of the area ranges from 860 to 840ft. above m.s.l. from north to south and from 865 to 840 ft. from north-east to south-west. The master slope of the area is to the south-west.

The tract is well watered by a number of streams of which the Saraswati *nala*, flowing centrally through the area in a south-west direction, is the most conspicuous. The Chautang *nala* drains the extreme southern part of the area and also flows southwestward.

There are also a few topographical depressions of which the Lend *Jhil*, south of Machrauli in the northern part of the area, is most important. Accumulation of rain water in these topographical lows often gives rise to local water-logging problems. In the central part of the area both the banks of the Saraswati *nala* are badly dissected by deep gullies which have turned this part into semi-badland by gully erosion.

GEOLOGY

The materials underlying the area consist of alluvial deposits of Quaternary age. The thickness of the alluvium here is not known but it is reasonably certain that it is at least several hundred feet thick throughout, with the possibility of crystalline rocks of the Delhi system occurring near the surface being fairly remote. At Ambala, wells have been drilled to depths greater than 1,000 ft. with no detectable change in type of deposition or in character of materials (Clegg, 1927 and Coulson, 1940, p. 59).

The alluvium, at least that of the shallower horizons, is derived from peripheral erosion, essentially all from the highlands in the northeast. These deposits are typical of those found generally throughout the Indo-Gangetic Plain, and consist, at least to the depths recently drilled, for which samples of drill cuttings would be examined, of a succession of clay, clay with *kankar*, sandy to silty clay, silt, fine to coarse sand, and sand with *kankar*. Locally, thin beds of gravel and cemented sands are occasionally present with the unconsolidated sand.

Near the surface, clay or clayey loam are the predominant materials which cover the underlying alluvial formations. The thickness of these materials varies from 5 to 15 ft.

The lithology of deposits underlying the Shahabad-Pipli-Ladwa area is known solely from inspection of the logs of 58 deep wells drilled by the French Group of Drilling Companies and which were made available to the Geological Survey of India through the courtesy of the authorities of the Punjab State. These wells range in depth from 220 ft. at well 64 near Bazidpur to 379 ft. at well 87 near Kanepla. The usual depth-range for most of these wells is 280 to 320 ft.

The summarised details of these well logs are given in Table 5 below :—

TABLE 5.—*Details of wells drilled by the French Group of Drilling Companies.*

State No.	Date Drilled	Depth (ft.)	Perforated interval (ft.)	Type of material
45	Feb. 1955	320	107-128, 147-208, 245-304 .	Sand, fine and coarse.
61	..	297	97-127, 147-285 . .	Sand, fine to coarse ; gravel.
62	..	308	....	....
63	..	300	....	....

TABLE 5.—*Details of wells, etc.*—contd.

State No.	Date Drilled	Depth (ft.)	Perforated interval (ft.)	Type of material
64	Nov. 1954	220	....	....
65	Jan. 1955	280	80-122, 142-214, 237-267 .	Sand, fine to coarse; gravel.
66	Nov. 1954	290	68-99, 135-239, 257-277 .	Sand medium to coarse; gravel.
67	Dec. 1954	280	....	....
68	Dec. 1954	290	....	....
69	..	242	....	....
70	Nov. 1954	296	86-105, 123-185, 222-281 .	Sand fine to coarse; gravel.
71	Dec. 1954	300	83-104, 124-165, 176-206, 226-255, 266-286	Sand, fine to coarse.
72	Jan. 1955	315	....	....
73	Jan. 1955	310	78-127, 150-211, 232-273 .	Sand, fine to coarse.
74	Jan. 1955	325	73-103, 124-266, 177-207, 227-247, 280-309.	Sand, fine to coarse; gravel.
75	Jan. 1955	365	76-126, 137-157, 187-245, 287-350.	Sand, fine and medium.
76	Nov. 1954	320	84-105, 144-268, 285-306 .	Sand, fine to medium; clay.
77	Jan. 1955	310	77-115, 146-176, 188-217, 284-287.	Sand, fine to coarse and gravel.
78	Jan. 1955	265	84-104, 115-248 . . .	Sand, fine to coarse with *kankar* and gravel.
79	Jan. 1955	262	83-112, 124-133, 145-248 .	Sand, fine to coarse, clay and gravel.
80	Jan. 1955	280	71-112, 134-166	Sand, fine to coarse; gravel.
81	Jan. 1955	340	74-125, 136-154, 185-206, 266-235, 259-329.	Sand, fine to coarse; gravel.
82	Jan. 1955	320	....	....
83	Jan. 1955	340	....	....
84	Dec. 1954	305	88-170, 189-218, 230-260, 271-292.	Sand, fine to coarse.

TABLE 5.—*Details of wells, etc.*—contd.

State No.	Date Drilled	Depth (ft.)	Perforated interval (ft.)	Type of material
85	Nov. 1954	260	84-208, 225-245 . .	Sand, medium to coarse ; clay with *kankar* ; gravel.
86	Jan. 1955	297	76-106, 116-196, 225-235, 264-284.	Sand, fine to coarse ; gravel.
87	Dec. 1954	379	87-108, 146-186, 222-264, 335-362.	Sand, fine to medium.
88	Nov. 1954	289	86-144, 163-204, 223-243, 261-281.	Sand, fine to coarse ; gravel.
90	Jan. 1955	330	86-117, 127-147, 168-209, 230-260, 283-312.	Sand, fine to medium ; gravel.
91	Jan. 1955	290	75-106, 116-146, 158-208, 228-269.	Sand, fine to coarse.
92	Jan. 1955	326	76-106, 125-145, 157-220, 240-269, 301-310.	Sand, fine to coarse ; gravel.
93	Jan. 1955	308	74-169, 201-210, 250-291 .	Sand, fine to coarse ; gravel.
94	Jan. 1955	320	76-116, 127-147, 185-226 245-265, 249-305.	Sand, fine to coarse ; clay, gravel.
95	Jan. 1955	340	....	....
96	Jan. 1955	340	137-188, 217-226, 238-268, 280-329.	Sand, fine to coarse ; gravel.
97	Dec. 1954	260	85-121, 142-246 . . .	Sand, fine to coarse ; gravel.
98	Dec. 1954	342	95-104, 144-174, 185-215, 226-256, 267-308.	Sand, fine to coarse with clay ; and *kankar*.
99	Dec. 1954	295	89-109, 130-171, 190-210, 228-267.	Sand, medium to coarse ; gravel.
100	Dec. 1954	300	84-124, 184-193, 223-274 .	Sand, medium to coarse ; sandy clay.
101	Dec. 1954	280	73-113, 124-175, 186-267 .	Sand, fine to coarse clay,
102	Dec. 1954	330	....	....
103	Dec. 1954	340	95-124, 173-224, 234-326 .	Sand, fine to coarse ; clay ; gravel.
104	Dec. 1954	290	87-126, 143-265 . . .	Sand, medium and coarse

TABLE 5.—*Details of wells, etc.*—concld.

State No.	Date Drilled	Depth (ft.)	Perforated interval (ft.)	Type of material
105	Dec. 1954	305	....	....
106	Jan. 1955	300	103-195, 207-237, 248-268	Sand, fine to coarse ; clay.
107	Jan. 1955	310	78-170, 188-218, 247-289	Sand, fine to coarse ; clay.
108	Jan. 1955	300	103-165, 185-236, 247-287	Sand, fine to coarse.
109	Dec. 1954	240	78-222	Sand, medium to coarse ; clay with *kankar*.
110	Dec. 1954	280	106-269	Sand, fine to coarse ; clay.
111	Dec. 1954	280	94-124, 144-206, 216-226, 237-267.	Sand, medium and coarse.
112	Feb. 1955	345	79-110, 121-140, 162-180, 191-231, 242-261, 291-331.	Sand, fine to medium ; gravel.
113	Dec. 1954	280	73-104, 124-216, 238-270	Sand, fine to coarse ; gravel.
114	Dec. 1954	246	87-213	Sand, fine and medium with clay and *kankar*.
115	Dec. 1954	280	87-213	Sand, fine and medium with clay and *kankar*.
116	—	360	95-113, 144-185, 204-225, 243-263, 274-283.	Sand, fine and coarse.
117	Dec. 1954	318	88-129, 147-188, 207-228, 246-267, 286-306.	Sand, fine and medium ; gravel.
118	Dec. 1954	320	84-126, 144-194, 251-302	Sand, medium and coarse with clay and *kankar*.

The boreholes, 27 inches in diameter, were drilled by the reverse rotary method. Six-inch casing was inserted in each and the annular spare was filled with gravel up to land surface. Of the 58 logs collected, nine were used to prepare a geological section showing continuity of strata in a north-south direction (Pl.3) ; additional logs were used to prepare an east-west section (Pl. 4). The locations of these sections are given in Pl. 1.

In the north-south geological section A-A′ the formation log for well 73 shows, in addition to four zones of fine to coarse sand less than 20 ft. thick and one zone below 280 ft. of indeterminate thickness, two major zones, one from 50 to 105 ft. and the other from 150 to 204 ft. below land surface. The existence of these major pervious zones as well as of the thinner ones are shown clearly in the electric log for this well as high resistance areas as well as areas of comparatively high negative self potential. Of these sandy zones, as delineated by both the formation and electric logs, the major two can be correlated very easily to adjacent wells both to the north and to the south. The sandy clay sequence at well 73 is reflected clearly at well 45, about five mile distant, and except for minor anomalies, shows amazing uniformity in deposition of sediments throughout this reach. This similarity is brought out still more clearly by a comparison of the electric log for well 73 with that for well 45. The whole sequence from 50 to 205 ft. at well 73 is reproduced closely at well 45 by the sequence from 55 to 205 ft. Both the resistance and self-potential-fluctuations are in close agreement. At well 45, however, some slight disagreement exists between the formation and electric logs and the graphic log for well 45 in the section has been modified accordingly. For instance, the electric log suggests a clay zone at 120-125 ft., which can be correlated with that at well 73 from 105 to 112 ft. With the bottom of the clay at about 150 ft. at well 73 correlating with that at 146 ft. at well 45, the clay stratum shown at 155-187 ft. in well 75 and at 160-183 ft. at well 62 must represent a lenticular deposit having no extension either at well 73 or at well 45.

Also, at well 45, the clay zone at 206-252 ft. is shown by the electric log to have greater effective porosity in the upper part, say to 236 ft. than in the lower. Hence, although the section 206-236 ft. was logged as clay by the driller, it is likely to be appreciably more permeable than the lower part. Therefore, this section, 206-236 ft., has been tied to the sand zone, 226-254 ft., at well 62 and the overlying clay at that well is then assumed to correspond with a clay stratum shown by the electric log of well 45 to exist there at 204-208 ft. The formation log of this well (No. 45) does not show this 4-ft. zone nor is there any evidence of a corresponding clay at well 73. In spite of these minor disagreements suggesting some definite degree of lenticularity of the thinner zones, the agreement from well to well is far closer than usually met with in alluvial deposits. The uniformity of deposition, at least from north to south, is far better than is common in non-marine sediments.

Geological section B-B′ was prepared to determine whether east-west correlation was also possible. Well No. 82 is common to both this section and to section A-A′. At this well, the lithological sequence is very much like that for well No. 73, at least for the two major zones which here appear at 46-112 and 154-200 ft. below land surface. However, the sandy zone which occurs below 285 ft. at well 73 and below 295 ft. at well 75 seems not to have been penetrated by this well. Laterally east and west from well 82, the zoning with relation to it seems not as regular as in the north-south section. To the west, at well 84, the zone which at well 82 is at 154-200 ft. seems to thin out. At well 84 this zone is thought to be represented by that at 188-216 ft., a decrease in thickness of 18 ft. This is offset, however, from the standpoint of water yield, by a general thickening of most of the other sandy strata present at this well from their overall thickness as represented by the sequence at well No. 82.

To the east, the upper zone (that from 46 to 112 ft. at well 82) seems to occur with little or no lithological change at well 81 and also at well 112. At greater depth, correlation such as that which could be accomplished with section A-A′ does not seem to be possible. Particularly at well 112 as well as at No. 81, alternation of thin sandy and clayey beds prevent any clear cut correlation. Only if electric logs were available it might be possible to project across on some distinct characteristic grouping of strata, at least through vertical thicknesses of small extent.

To the south, in the vicinity of well 45, electric logs were run on both well 32 and well 33, respectively one mile south-west and 1·4 miles south-east of well 45. At well 32, zones of fairly high effective porosity are shown at following depths : 42-66, 120-150, 164-201, 210-250 and 255-266 ft. below land surface. These are zones that probably would be reported as sand in the formation log. At well 33, zones of high resistance and high negative S. P., suggesting the existence of coarse materials are at the following depths : 35 to 56 ft., 90 to 108 ft. intermittently from 150 to 205 ft., 215 to 230 ft., and 256 to 333 ft., except for a 7-ft. clay band at 275-282 ft. below land surface.

A comparison of logs of all three wells, Nos. 45, 32, and 33, shows the following points of similarity :

1. A clayey zone at 116 ft. on log 45 is seen on log 32 at about the same depth and, except for adjacent configuration that renders the correlation less positive, on log 33 as well, also at about the same depth.

2. The whole zone from 237 to 252 ft. (an area of low effective porosity, hence suggesting a clayey stratum) at well 45 is seen at 232-256 ft. at well 32 and at 231-255 ft. at well 33.

3. The slight indentation of the S. P. curve at 272 ft. at well 45 may represent the beginning of a lenticular clay zone that is represented by the very well defined positive fluctuation at 270 ft. at well 32 and at 276 ft. at well 33.

The foregoing points of similarity confirm the concept that although individual beds may thicken, thin, or disappear, it seems generally possible to correlate from well to well on the basis of groups of zones with similar overall electrical characteristics ; however, thin "marker" beds may persist through long distances, giving rise to a characteristic indentation of either or both the S. P. and resistance curves, from which correlation is possible.

From the study of N.—S. generalised geological section it is seen that in general, granular materials comprising medium to coarse-grained sands and gravels are more abundant in the northern part than in the southern and such materials tend to decrease progressively in coarseness from north to south. Coarse materials range from a maximum concentration of 58 per cent. in well No. 111 near Jalkheri to a minimum of 18 per cent. in well No. 62 near Mathana. Perusal of Table 6 brings out the significant changes in the concentration of coarse materials in wells rom north to south along the section A-A′.

TABLE 6.—*Data for coarse materials in some selected deep wells along Geological Section A-A'.*

Tubewell No.	Depth below land surface (ft.)	Percentage of coarse materials : sand, medium to coarse; gravels
111	280	58
104	290	51
95	340	46
90	330	41
82	320	41
73	310	57
75	365	38
62	308	18
45	320	26

In general, based on data available to the author, a well, anywhere within the area, drilled usually to a depth 300 to 400 ft. below land surface, is fairly certain to be productive.

Examination of the drill cuttings recovered from one or two of the deep wells during drilling shows that the sands, rounded or sub-rounded in shape, vary considerably in diameter, with a tendency towards preponderance of fine materials. It would seem that, in as much as gravel-packed wells are singularly successful here and also because of the general fineness of the water yielding materials, it would be sound practice to continue with this type of well construction. That is, it is doubtful if non-gravel-packed wells, expected to have a high yield, would be worthwhile to attempt unless the use of fine mesh screen of rugged and accurate construction can be introduced. However, the practice of gravel-packing of the wells through the entire depth drilled, is of doubtful value.

OCCURRENCE OF GROUNDWATER

General Features

Rainfall is the primary source of the groundwater occurring in the Shahabad-Pipli-Ladwa area. The water enters the ground by direct penetration of rain or by infiltration from ponded areas that are formed during the summer monsoon, or from the ephemeral streams that are in existence during that period. That the ground underlying such areas locally becomes waterlogged points to the efficacy of such ponds as a means of recharge.

As the groundwater body generally is not static but normally moves down the gradient with speeds that may range from a few tens to a few hundreds of feet each year, an additional source of recharge higher up the gradient is implied. The magnitude of this source may be as great as that derived from penetration of a portion of the rain falling directly on the area. However, with the meagre data now on hand, a quantitative value cannot be determined.

Discharge of groundwater takes place by transpiration, by movement down the gradient to contiguous areas, by economic yield through open wells, and possibly by seepage to *nalas*.

In the area the groundwater occurs in a very thick zone of saturation from or within a few feet to a depth as yet unknown. Although both clay and sand strata are saturated, only the latter will yield water to wells at an economic rate. This is because of the great difference in permeability of the two types of material. Although the field staff was not given the opportunity to make detailed pumping tests to obtain data from which permeabilities could be computed, similar water yielding material encountered elsewhere often have permeabilities within the range 800 to 2,000 g.p.d./ft. The permeability of clayey deposits may be as low as or even less than one g.p.d./ft.

The more pervious zones, that will yield water in sufficient quantity to be of importance as a source of supply, are known as "aquifers".

By definition, both confined and nonconfined waters occur in the area. The static water level in the open wells represents a free water surface known as the "water-table". The levels in wells tapping deep water yielding zones overlain by clay strata rise some distance above the top of the confining strata. Such water is under pressure and exists under "sub-artesian" conditions (Wisler and Brater, 1949).

Because the area is virtually untapped and because none of the confining layers are of great regional extent nor are their permeabilities zero, both shallow and deep wells must have a common water-level. Following a period of many years of heavy draft from deep wells, the levels in these wells will become different from those in the shallow open wells. Whether they will be lower or higher cannot now be determined. The exact position will depend on the inter-relationship between the ability of the shallow zone to supply recharge in quantity through intervening clay barriers and the ability of the deeper zones or aquifers to obtain recharge from laterally contiguous zones of comparable depth.

Shallow Zones Tapped by Open Wells

Doubtless, many hundreds of shallow open wells exist throughout the area. Of these, during the present investigation, depth-to-water measurements were obtained in 84. Details of the wells so measured are tabulated in Appendix 3. The depths of the wells visited range from 47 ft. below land surface at 53C/13-1C21, 3/4 mile northeast of Bodhi, to 22 ft. at well 53B/16-3B2, near Khanpur.

Depth to water-level below land surface varies from 20 to 25 ft. in general ; a depth of 30·16 ft. was noted at 53B/16-3B7 near Morthala.

The form and slope of the water-table is only approximately known as there are not sufficient data available to prepare a water-table contour map. In general, however, the water-table elevation declines from north-east to south-west, roughly sub-parallel to the slope of the country.

Water-level altitudes determined by interpolation from large scale contour map of the area are found to vary from about 842 ft. at well 53B/16-2B1, south of Shahabad at the northern tip of the area and at well 53B/16-2C2 in the north-eastern part to about 817 ft. at well 53C/13-1B4 near Unri which is situated at the south-western end of the area and to 818 ft. at well 53C/13-1B1, about half a mile north of Pipli.

From the foregoing it is gathered that the water-table has an average gradient of about two feet per mile from north to south and about three feet per mile from north-east to south-west. Hence the general direction of water movement is from north-east to south-west.

Well logs show that, fine sand is penetrated at many places from 10 to 30 ft. below land surface. Hence, many shallow open wells yield water from this material which may not be appreciably different from most of the materials making up the aquifers at depth. Doubtless the overlying soil material, although clayey locally, has sufficient permeability to yield small quantities of water through large diameter open wells. The fine sand, where tapped by open wells, is a fairly good aquifer. Many report that no appreciable lowering of level occurs while pumping. Some lowering must occur, of course, but because of the low pumping rates it is not detectable by casual inspection.

Nothing is known of the seasonal or long term fluctuation of level in the shallow wells. Based on water-level measurements in each of the 84 wells, it is estimated that if the water-level were to decline 10 ft., 51 out of the 84 wells would go dry and need to be deepened ; and if the level were to decline an additional 5 ft., 72 wells or about 88 per cent. would go dry. For this area, the possibility of, say, a 10 ft. decline is remote indeed, except possibly in a protracted succession of drought years. The process of correlating expected rise or fall in levels in relation to rainfall trends as depicted in Plate 2, Fig. 2 is at present impossible due to the absence of any long term water-level records.

Considering the possibility of lowering of water-levels by pumping, a known amount of decline can easily be interpreted in terms of total yield. If an estimate of 35 per cent. is made for the specific yield of the fine sand tapped by many shallow wells in the area, a decline of 10 ft. throughout the 78 sq. mile area would mean a total yield of 175,000 acre-ft., or about 49,000 million gallons. The possibility of extracting this quantity, even through several pumping seasons, is not likely to occur. Of course through any interval of use, losses of various sorts will occur, but these, as well as at least a part of the consumptive use, will be offset by induced natural recharge.

Deeper Zones Tapped by Tubewells

Fragmentary information suggests that water-levels in the deeper aquifers are the same as in the shallow wells. This is to be expected because of the presumed regional lack of continuity of confining clays as well as to the fact that the area is still virtually untouched in so far as groundwater yield is concerned.

Pumping test data for tubewells indicate that zones tapped, to depths less than 400 ft. below land surface, are generally prolific and yields of 550 to 600 g.p.m. are common. For a detailed tabulation of the hydraulic characteristics of the tubewells in the area, Table 7 has been included in this report. Specific capacities of wells in g.p.m./ft. of drawdown range from 26 at well 77 to 63.5 at well 81. Although specific capacity is tied up with well construction peculiarities, in general the more pervious aquifer will allow the greater specific capacity provided that the aquifers being compared are of about the same thickness and provided also that the wells tapping each are similar in construction.

TABLE 7.—*Hydraulic characteristics of tubewells in the area.* (From records on file in Punjab State offices).

Well No.	Depth	Static water-level (ft.) below land surface	Date of measurement	Drawdown (ft.)	Specific capacity (g.p.m./ft.)	Yield (imp. g.p.m)
61	297	27½	—	—	—	567
62	308	26	Dec. 21, 1955	16½	34½	567
63	300	28	—	—	—	570
64	220	23½	—	—	—	582
66	290	17½	—	15	41	615
67	280	18½	—	15	43½	654
68	290	—	—	—	—	—
69	242	25	—	12½	51½	642
71	300	24½	Feb. 4, 1955	19	32	605
72	315	21½	Jan. 8, 1955	9	62½	560
76	320	25	Dec. 22, 1954	14	41½	583
77	310	27	Feb. 22, 1955	22	26	568
79	262	24½	Feb. 8, 1955	19	30½	582
80	280	27½	Feb. 21, 1955	13	47½	615
81	340	25	Feb. 20, 1955	10	63½	635
82	320	12	Feb. 5, 1955	11	54	596
83	340	27½	Feb. 4, 1955	15	38	566
84	305	30	Feb. 6, 1955	11	51	560
85	260	19½	Jan. 5, 1955	13	48	625
86	297	19½	Jan. 6, 1955	13	48½	633
87	379	22	Jan. 7, 1955	15	38½	577
88	289	25	Jan. 9, 1955	13	48	625

Well No.	Depth	Static water-level (ft.) below land surface	Date of measurements	Drawdown (ft.)	Specific capacity g.p.m./ft.	Yield (imp. g.p.m).
92	326	18	Feb. 1, 1955	12	53½	642
93	308	23	Jan. 30, 1955	12	52	624
94	320	23½	Feb. 17, 1955	15	39½	590
97	260	24	Jan. 13, 1955	11½	51	590
98	342	22½	Jan. 7,1955	17	34½	590
99	295	24	Dec. 10, 1954	15	37	556
100	300	21½	Jan. 8, 1955	9	62	560
101	280	23½	Jan. 8, 1955	12	50½	605
102	330	24	Jan. 14, 1955	11	53½	590
103	340	26½	Jan. 14, 1955	12	47½	570
104	290	26	Jan. 14, 1955	12	47½	570
105	305	28	Jan. 16, 1955	10	56	560
106	300	25½	—	18	30½	549
108	300	25	Jan. 17, 1955	15	35	522
109	240	26½	—	20½	29	589
110	280	26	Jan. 16, 1955	12	52	623
111	280	24	Jan. 15, 1955	12	49	590
113	280	23	Jan. 8, 1955	21	28½	595
115	280	25	Dec. 11, 1954	14	41½	582
118	320	25	Jan. 21, 1955	12	45½	549

CHEMICAL QUALITY OF GROUNDWATER

Shallow Zones Tapped by Open Wells

In the course of the groundwater investigation in the area, 37 wells were sampled for chemical analysis between January 22 to February 12, 1955. The data obtained from the analysis of these are presented in Table 8. A considerable range in concentration of the constituents determined was found. Chloride ranges from 6 to 330 p.p.m., bicarbonate from 182 to 879 p.p.m. and total hardness as $CaCO_3$ from 145 to 800 p.p.m.

These data have also been utilised for preparing Plates, 5, 6 and 7 and are shown graphically thereon. These three plates show, respectively, the areal distribution of chloride, bicarbonate, and total hardness. The concentration of dissolved salts may vary considerably from year to year as well as seasonally. Thus, the pattern of quality distribution shown on these plates, although valid for the period January-February, 1955, may be appreciably different in other seasons or may vary from year to year.

The isochlor map (Pl. 5) shows that the shallow groundwater from most of the area under study is very low in the concentration of chloride, usually below 50 p.p.m. Only in the extreme south-western part is the concentration of the chloride ion over 100 p.p.m. The maximum concentration of 330 p.p.m. has, however, been noted in the water from well 53C/13-1C20, near Bodhi.

The bicarbonate content of the groundwater (Pl. 6) is generally high. The usual range in most of the area is over 300 p.p.m. The maximum concentration of bicarbonate has been found in the extreme southern part as also in the west-central parts where it is over 500 p.p.m. Comparatively low concentration of bicarbonate occurs in the groundwater from Baholi and Srisma in the south-western part, and Bodla and Takti in the central parts of the area.

TABLE 8.—*Partial chemical analysis of water samples from wells in the Shahabad-Pipli-Ladwa area.*

(Analyses by S. R. Maitra, Assistant Chemist, Geological Survey of India).

Well Number	Date of collection (1955)	Chloride (p.p.m.)	Bicarbonate (p.p.m.)	Total hardness as $CaCO_3$ (p.p.m.)	Conductivity (micromhos).	pH
Open Wells:						
53B/16-2B3	29-1-55	9	348	180	587	7·9
53B/16-2B6	12-2-55	20	415	270	780	7·4
53B/16-2B7	12-2-55	22	348	250	585	7·5
53B/16-2B8	12-2-55	53	454	395	1,060	7·4
53B/16-2B9	12-2-55	20	308	190	634	7·3
53B/16-2C2	12-2-55	28	414	295	800	7·1
53B/16-2C3	12-2-55	56	374	315	800	7·8
53B/16-2C4	12-2-55	45	426	325	905	7·6
53B/16-3B2	29-1-55	112	560	500	1,500	7·7
53B/16-3B8	30-1-55	100	585	360	1,375	7·7
53B/16-3C1	23-1-55	28	272	270	617	7·7

Well Number	Date of collection (1955)	Chloride (p.p.m.)	Bicarbonate (p.p.m.)	Total hardness as $CaCo_3$ (p.p.m.)	Conductivity (micromhos).	pH
53B/16-3C2	23-1-55	11	313	185	531	7·8
53B/16-3C4	27-1-55	11	354	275	546	7·5
53B/16-3C6	27-1-55	39	303	255	652	7·8
53B/16-3C8	27-1-55	25	374	250	755	7·8
53B/16-3C9	28-1-55	22	282	225	540	7·9
53B/16-3C12	31-1-55	31	303	220	680	7·9
53B/16-3C17	30-1-55	45	480	280	946	7·7
53B/16-3C18	12-2-55	31	446	285	845	7·7
53B/16-3C21	11-2-55	39	425	270	948	7·6
53C/13-1B1	30-1-55	14	323	195	561	7·9
53C/13-1B4	4-2-55	140	625	425	2,220	7·8
53C/13-1C1	25-1-55	9	500	375	722	7·5
53C/13-1C3	25-1-55	203	585	405	1,690	7·3
53C/13-1C5	25-1-55	14	368	250	651	7·1
53C/13-1C7	25-1-55	25	399	275	770	7·6
53C/13-1C11	26-1-55	6	182	145	298	7·9
53C/13-1C16	8-2-55	19	292	265	606	7·9
53C/13-1C17	6-2-55	28	409	330	786	8·0
53C/13-1C20	6-2-55	330	879	800	3,910	8·0
53C/13-1C22	7-2-55	39	416	285	856	7·9
53C/13-1C23	7-2-55	169	615	695	1,850	7·6
53F/4-3A3	10-2-55	25	449	280	770	7·8
53F/4-3A7	11-2-55	15	278	190	510	7·8
53F/4-3A10	10-2-55	45	470	460	1,105	7·7
53G/1-1A1	25-1-55	13	368	270	630	7·6
53G/1-1A2	8-2-55	8	424	370	692	7·8
Tubewells :						
77	27-1-55	8	374	230	646	7·6
80	27-1-55	9	272	180	486	8·0

Study of the total-hardness map (Pl.7) shows that the shallow groundwater is also characterised by high concentration of calcium and magnesium. The water from most of the wells is fairly hard, usually over 200 p. p. m. Water from the southern parts of the area and also from Kharindwa, Machrauli, Kalalmajra, and Kaulapur in the north is very hard, over 300 p.p.m. Moderately hard water is found around Baholi, Shekhpur, and Chharpura in the south-western part of the area. In the extreme northern part, as well as near Shahabad, moderately hard water, from 180 to 190 p.p.m., occurs.

From the study of the quality-distribution patterns (Pls. 6 & 7) it appears that the hardness of the groundwater is related mainly to the concentration of bicarbonate, inasmuch as increase or decrease in the concentration of bicarbonate is reflected in the similar increase or decrease in the total hardness for specific areas.

From the foregoing discussion it can be seen that although the water from the open wells is potable and is suitable for irrigation the total hardness is high so that it is not considered good for laundering purposes. However, it can be said, that the water from the shallow water yielding zone can, with only a few exceptions, be used for all normal purposes.

Deeper Zones Tapped by Tubewells

Not much information is available regarding the chemical quality of groundwater occurring in the deeper aquifers tapped by tubewells. These wells could not be sampled for chemical analyses owing to lack of opportunity. It is understood that most of these wells were, however, sampled by the State agencies for chemical analyses. The relevant State agencies were accordingly requested to furnish the Geological Survey of India with the chemical results available with them.

Only two wells (Nos. 77 and 80) were sampled by the field staff of the Geological Survey of India. Examination of the results of partial chemical analyses of these two wells reveals that there is practically no significant difference in the chemical quality of waters from the shallow and deep zones. Water from the deep well, like its counterpart from the shallow zone, is low in chloride, high in bicarbonate and total hardness. The meagre data from the two wells also should not, however, be made the basis for general conclusion regarding the chemical quality of water from deeper zone.

CONCLUSIONS

The Shahabad-Pipli-Ladwa area forms a part of the wide spread Indo-Gangetic alluvial plain and is more or less flat without any conspicuous topographical features. The tract is entirely covered by alluvial deposits of Quaternary age consisting of a succession of clay, clay with *kankar*, sandy to silty clay, silt, fine to coarse sand, and sand with *kankar*. Locally thin beds of gravel and cemented sands are occasionally present with unconsolidated sands. The thickness of the alluvium here is not precisely known, but it is reasonably certain that it is at least several hundred feet thick throughout.

Study of the generalised geological sections, prepared on the basis of formation logs of 58 deep wells drilled in the area, reveals the existence of two major zones of coarse granular materials at depths of 46-112 ft. and 150- 205 ft. in addition to the minor ones. The coarser materials (sand, medium to coarse gravel) are more abundant in the northern part than in the southern and progressively decrease from a maximum of 58 per cent. at well No. 111 in the northern part to 18 per cent. at well No. 62 in the southern part. Sediments are found to have been under more uniform condition in N.-S. direction than in the E.-W.

Comparison of electrical logs of well Nos. 4, 5, 33 and 32 brings out certain common features which suggest that although individual beds may thicken, thin or disappear, it seems generally possible to correlate from well to well on the basis of groups of zones with similar overall electrical characteristics.

In general, it may be stated that throughout the area, a well, if drilled to a depth of 300-400 ft. is fairly certain to be productive.

The groundwater in the area under study occurs in a very thick zone of saturation from or within a few feet to a depth as yet unknown. The depth to water in general varies from 20 to 25 ft. The maximum depth of 30·16 ft. was noticed at well No. 53B/16-3B7 near Morthala (30°04′ : 76°55′ ; 53 B/16). The depth of wells range from 67·16 ft. at 53C/13-1C21, 3/4 mile north-east of Bodhi (29°56′ 20″ : 76°51′45″ ; 63 C/13) to 21·59 ft. at well No. 53B/16-3B2 near Khanpur.

The water-table elevation declines from north-east to south-east and is roughly sub-parallel to the slope of the country. Based on the water level measurements it seems that if the water levels were to recede 10 ft., 51 out of the shallow open wells canvassed would go dry and would need to be deepened ; and if the water-level were to recede an additional 5 ft. 72 wells or about 88 per cent. would go dry. However, for this area the possibility of a 10 ft. recession is slender indeed.

Available data on tubewells suggest that the water levels in them are same as that in the shallow wells. Pumping test data for the tubewells indicate that zones, tapped to depths less than 400 ft. are generally prolific, and yields of 550 to 600 g.p.m. are common. The specific capacity of wells ranges from 26 at well No. 77 to 63·5 at well No. 81.

Partial chemical analyses of about 37 samples of water from open wells and two from tubewells show that the concentration of chloride and bicarbonate varies from 6 to 330 p.p.m. and 182 to 879 p.p.m. respectively. The total hardness calculated as $CaCO_3$ shows a variation from 145 to 800 p.p.m. The groundwater in general is low in chloride, but high in bicarbonate and total hardness. The water from all sources examined is found to be potable and is considered suitable for irrigation. The total hardness being high the water may not be good for laundering purposes.

SUGGESTIONS FOR FURTHER WORK

1. The investigations which form the basis for this report on the groundwater conditions in the Shahabad-Pipli-Ladwa area are necessarily of rather limited scope and deal only with the general features of groundwater occurrence. The work is not of sufficiently detailed type to permit the quantitative assessment of the groundwater potentialities. It is suggested that detailed inventory work may be taken up which should attempt to determine the groundwater recharge and discharge.

2. Since seasonal fluctuation of water-level in the area is also not known, a programme for periodic measurements of water-level in selected key wells is also considered worthwhile.

3. Slope and gradient of water-table is also not precisely known, because water-table contour map could not be prepared due to lack of reduced levels for wells canvassed. Since a water-table contour map is of paramount importance in determining the direction of groundwater movement, a programme for preparation of water-table contour map through determination of reduced levels for suitable key wells is recommended.

4. Systematic pumping tests in tubewells throughout the area should be made in order to determine the yield characteristics of the wells and also coefficients of transmissibility and permeability and storage coefficient of aquifers. The data obtained from such tests will be of use in suggesting economic spacing of tubewells.

5. Chemical quality of water, tapped from deep zones through tubewells, is not adequately known owing to lack of chemical data, in view of which it is suggested that a suitable number of tubewells should be sampled for partial as well as complete chemical analyses during the next period of field investigation in the area.

BIBLIOGRAPHY

CLEGG, E. L. G., 1927.—The Ambala Boring of 1926-27. *Rec. Geol. Surv. Ind.*, Vol. 60, Pt. 3, pp. 303-307.

COULSON, A. L., 1940.—The geology and underground water-supply of Calcutta, Bengal, with special reference to tubewells. *Mem. Geol. Surv. Ind.*, Vol, 76, Water-supply Paper No. 1.

GOVERNMENT OF PUNJAB, 1918.—Punjab District Gazetteers, Vol. VI-A, Karnal District.

WISLER, C. O., AND BRATER, E. F., 1949. –Hydrology, New York, John Wiley & Sons.

APPENDICES

APPENDIX 1.

Selected logs of Tubewells drilled in the Shahabad-Pipli-Ladwa area, by the French Group of Drilling Companies, 1954-55:

Tubewell No. 32. Drilled February 1954. Perforated interval not known.

Material	Thickness (ft.)	Depth (ft.)
Clay, surface	9	9
Clay, brown	36	45
Sand, fine	20	65
Clay, brown	55	120
Sand, fine	20	140
Sand, medium	15	155
Sandy clay and pebbles	5	160
Sand, micaceous	10	170
Sand, coarse and medium	20	190
Sand, medium to coarse	13	203
Clay, brown	9	212
Sand, fine to medium	24	236
Clay, brown	21	257
Sand, coarse	11	268
Clay, brown	7	275
Sand, coarse and pebbles	49	324
Sand, medium and coarse	4	328

APPENDIX 1—*contd.*

Tubewell No. 33. Drilled February 1955. Perforated interval not available.

Material	Thickness (ft.)	Depth (ft.)
Clay, surface	8	8
Sand, fine	2	10
Clay, brown	10	20
Sand, fine	10	30
Clay, brown	10	40
Sand, fine	20	60
Clay	85	145
Silt and pebbles	27	172
Sand, medium	33	205
Clay	15	220
Sand, cemented and pebbles	10	230
Clay	25	255
Sand, medium to coarse	21	276
Clay, brown	8	284
Sand, coarse	21	305
Sand, coarse and pebbles	25	330
Sand, coarse	10	340

Well No. 45. Drilled February 1955. Perforated Interval 107-128, 147-208, 245-304 ft. below land surface.

Material	Thickness (ft.)	Depth (ft.)
Surface clay	8	8
Sand, fine	17	25
Clay	30	55
Sand, Fine	10	65
Clay	10	75
Sand, fine	55	130
Clay	16	146
Sand, coarse, and pebbles	22	168
Sand, fine	16	184
Sand, medium	10	194
Sand, coarse	12	206
Clay	46	252
Sand, fine	28	280
Sand, coarse, and pebbles	40	320

APPENDIX 1—*contd.*

Well No. 62. Date of drilling and perforated interval not known.

Material	Thickness (ft.)	Depth (ft.)
Top soil	10	10
Clay with *kankar*	49	59
Sand, fine	12	71
Sand, medium	21	92
Clay and *kankar*	43	135
Sand, fine	5	140
Sand, medium	20	160
Clay	23	183
Sand fine	27	210
Clay and *kankar*	16	226
Sand, fine	28	254
Clay	39	293
Sand, medium, with cemented sand and pebbles	15	308

Well No. 73. Drilled January 1955. Perforated interval 78-127, 150-211, 232-275 ft. below land surface.

Material	Thickness (ft.)	Depth (ft.)
Clay	21	21
Sand, medium	19	40
Clay	10	50
Sand, fine	10	60
Sand, medium	30	90
Sand, coarse	15	105
Clay	7	112
Sand, coarse	15	127
Clay and *kankar*	23	150
Sand, medium	54	204
Clay and *kankar*	24	228
Sand, medium, and gravel	22	250
Clay	8	258
Sand, fine	14	272
Clay	8	280
Sand, fine	5	285
Sand, coarse	25	310

APPENDIX 1—*contd.*

Well No. 75. Drilled January 1955. Perforated interval 76-176, 137-156, 187-245, 287-350 ft. below land surface.

Material	Thickness (ft.)	Depth (ft.)
Surface clay	10	10
Sand, fine, brown	10	20
Sand, fine and medium	25	45
Clay	5	50
Sand, medium	26	76
Sand, fine and medium, cemented sand	20	96
Clay and *kankar*	17	113
Sand, fine	10	123
Clay and *kankar*	14	137
Sand, medium	18	155
Clay, and *kankar*	32	187
Sand, fine	33	220
Sand, medium	18	238
Clay	31	269
Sand, fine	15	284
Sand, medium	4	288
Clay and *kankar*	7	295
Sand, fine and cemented sand	9	304
Sand, medium, pebbles and cemented sand	10	314
Sand, fine	29	343
Sand, medium	22	365

APPENDIX 1—*contd.*

Well No. 78. Drilled January 1955. Perforated interval 84-104, 115-248 ft. below land surface.

Material	Thickness (ft.)	Depth (ft.)
Surface clay	10	10
Clay	10	20
Sand, fine	20	40
Clay	10	50
Sand, fine, and *kankar*	14	64
Clay	21	85
Sand, fine	16	101
Clay and *kankar*	14	115
Sand, fine, and *kankar*	37	152
Sand, medium	4	156
Sand, coarse, and *kankar*	10	166
Sand, medium, and gravel	6	172
Sand, fine	10	182
Clay and *kankar*	3	185
Sand, medium, and *kankar*	5	190
Sand, coarse, and cemented sand	18	208
Sand, medium, and cemented sand	5	213
Sand, very fine	8	221
Clay and sand, fine	2	223
Clay and *kankar*	13	236
Sand, fine	29	265

APPENDIX 1—*contd.*

Well No. 81. Drilled January 1955. Perforated interval 74-125, 136-154, 185-206, 226-235, 259-329 ft. below land surface.

Material	Thickness (ft.)	Depth (ft.)
Surface clay	15	15
Sand, fine	22	47
Clay	5	52
Sand, fine	12	64
Sand, medium	48	112
Clay and *kankar*	23	135
Sand, fine	18	153
Clay and *kankar*	11	164
Sand, fine	14	178
Clay	7	185
Sand, fine	10	195
Sand, medium	15	210
Clay and *kankar*	20	230
Sand, fine, cemented sandstone	12	242
Clay, hard, and *kankar*	19	261
Sand, fine and cemented sandstone	12	273
Sand, fine	11	284
Sand, medium	18	302
Cemented sand, hard	3	305
Sand and cemented sand	2	307
Clay and gravel	3	310
Sand, fine, and pebbles	5	315
Sand, medium, and cemented sand	6	321
Sand, coarse, and gravel	7	328
Clay	4	332
Sand, fine	8	340

APPENDIX 1—*contd.*

Well No. 82. Drilled January 1955. Perforated interval not known.

Material	Thickness (ft.)	Depth (ft.)
Top soil	10	10
Sand, fine	15	25
Clay, sticky	21	46
Sand, medium	66	112
Clay	5	117
Sand, fine	8	125
Sand, medium	9	134
Clay	20	154
Sand, fine	28	182
Sand, medium	18	200
Clay	25	225
Sand, fine and *kankar*	10	235
Sand, medium	11	246
Sand, coarse, and gravel	6	252
Clay	23	275
Sand, medium, and gravel	27	302
Clay	18	320

Well No. 84. Drilled December 1954. Perforated interval 88-170, 189-218, 230-260, 271-292 ft. below land surface.

Material	Thickness (ft.)	Depth (ft.)
Top clay	10	10
Clay	8	18
Sand, fine	32	50
Clay	10	60
Sand, fine	20	80
Sand, medium	38	118
Clay	10	128
Sand, medium and fine	40	168
Clay and *kankar*	20	188
Sand, fine	28	216
Clay and *kankar*	14	230
Sand, fine, and cemented sand	4	234
Sand, coarse	18	256
Clay	9	265
Sand, fine	25	290
Sand, coarse, and cemented sand	15	305

APPENDIX 1—*contd.*

Well No. 90. Drilled January 1955. Perforated interval 86-117, 127-147, 168-209, 230-260, 283-312 ft. below land surface.

Material	Thickness (ft.)	Depth (ft.)
Clay, surface	10	10
Clay and *kankar*	15	25
Sand, fine and medium	26	51
Clay	8	59
Sand, medium	23	82
Sand, fine	35	117
Clay and *kankar*	13	130
Sand, fine	15	145
Clay	15	160
Sand, fine	15	175
Sand, medium and cemented sand	10	185
Sand, medium	20	205
Clay	30	235
Sand, medium	10	245
Sand, medium, and gravel	20	265
Clay	20	285
Sand, medium	29	314
Clay	16	330

Well No. 95. Drilled January 1955. Perforated interval not known.

Material	Thickness (ft.)	Depth (ft.)
Clay	30	30
Sand, fine	10	40
Clay	75	115
Sand, medium	10	125
Clay	17	142
Sand, medium	10	152
Clay	20	172
Sand, medium	14	186
Sand, coarse, and cemented sand	10	196
Clay and *kankar*	10	206
Sand, medium	26	232
Clay and *kankar*	8	240
Sand, medium	10	250
Sand, coarse	26	276
Clay	10	286
Sand, medium	37	323
Sand, coarse	13	336
Clay	4	340

APPENDIX 1—*contd.*

Well No. 104. Drilled December 1954. Perforated interval 87-126, 163-265 ft. below land surface.

Material	Thickness (ft.)	Depth (ft.)
Top soil	18	18
Sand, fine	37	55
Clay	30	85
Sand, medium	41	126
Clay	18	144
Sand, medium	42	186
Sand, coarse	8	194
Clay and *kankar*	6	200
Sand, medium	15	215
Sand, fine	5	220
Sand, medium	20	240
Sand, coarse	10	250
Sand, medium	15	265
Clay and *kankar*	15	280
Sand, fine	10	290

Well No. 111. Drilled December 1954. Perforated 84-124, 144-206, 216-226, 237-267 ft. below land surface.

Material	Thickness (ft.)	Depth (ft.)
Clay, surface	10	10
Clay	5	15
Sand, fine	5	20
Sand, medium	30	50
Clay, sandy	10	60
Clay	20	80
Sand, medium	10	90
Sand, coarse	35	125
Clay and *kankar*	19	144
Sand, medium	16	160

APPENDIX 1—*concld.*

Well No. 111. Drilled December 1954. Perforated 84-124, 144-206, 216-226, 237-267 ft. below land surface—*contd.*

Material	Thickness (ft.)	Depth (ft.)
Sand, medium, and *kankar*	14	174
Sand, coarse, and *kankar*	26	200
Clay	14	214
Sand, fine	16	230
Clay	3	233
Sand, medium	17	250
Sand, coarse	15	265
Clay and *kankar*	15	280

Well No. 112. Drilled February 1955. Perforated interval 79-110, 121-140, 162-180, 191-231, 242-261, 291-331 feet below land surface.

Material	Thickness (ft.)	Depth (ft.)
Top Clay	10	10
Sand, fine	17	27
Clay	28	55
Sand, fine	20	75
Sand, medium, and *kankar*	33	108
Clay	9	117
Sand, fine and *kankar*	11	128
Clay	6	134
Sand, fine	8	142
Clay and *kankar*	18	160
Sand, medium	18	178
Clay	17	195
Sand, fine	5	200
Sand, medium	25	225
Clay	21	246
Sand, fine	18	264
Clay and *kankar*	9	273
Sand, fine	4	277
Clay	14	291
Sand, fine	15	306
Clay and *kankar*	11	317
Sand, medium and pebbles	28	345

APPENDIX 2.

Locality Index.

Place Name	Geographical (Lat.)	Co-ordinates (Long.)	Sheet Number
Baholi	29°59′ 40″	76°54′ 45″	53 C/13
Bazidpur	29°59′ 10″	76°54′ 15″	53 C/13
Bodhi	29°56′ 20″	76°56′ 45″	53 C/13
Bodla	30°01′ 00″	76°56′ 25″	53 B/16
Chharpura	30°00′ 15″	76°55′ 50″	53 B/16
Jalkhere	30°04′ 25″	76°55′ 20″	53 B/16
Kalamazra	30°04′ 05″	76°55′ 50″	53 B/16
Kanepla	30°03′ 05″	76°52′ 05″	53 B/16
Kaulapur	30°01′ 50″	76°54′ 45″	53 B/16
Kherindwa	30°10′ 00″	76°51′ 45″	53 B/16
Kurukshetra	29°58′ 15″	76°51′ 05″	53 C/13
Ladwa	29°59′ 40″	77°02′ 40″	53 G/1
Machrauli	30°05′ 25″	76°54′ 35″	53 B/16
Morthala	30°04′ 00″	76°00′ 55″	53 B/16
Pipli	29°58′ 35″	76°53′ 35″	53 C/13
Shahabad	30°10′ 00″	76°52′ 15″	53 B/16
Shekhpur	29°59′ 25″	76°55′ 30″	53 C/13
Sirsma	29°58′ 15″	76°55′ 05″	53 C/13
Tatki	30°01′ 50″	76°57′ 10″	53 B/16
Thanesar	29°58′ 15″	76°50′ 00″	53 C/13
Umri	29°56′ 55″	76°54′ 40″	53 C/13

Hydrologic Data on Open Wells in the Shahabad-Pipli-Ladwa

Well No.	Location	Owner	Type[1]	Depth (ft.) (below land surface)	Dimension (ft.) Diameter	Method of lift[2]	Nature of water bearing material
1	2	3	4	5	6	7	8
53B/16-2B2 .	About 90 yds. N. 30°W of the milestone indicating 106 miles from Delhi on G. T. Road ; on the Western side of the road by the Eastern fringe of the village Ratangarh.	Common Village well.	Dg.	24	3·4	..	Sand
53B/15-2B3 .	S. 80°E. of Ratangarh and S. 50°W. of the village Kishangarh. About 230 ft. east of the village road leading to Kishangarh.	Puran Singh Sadhu Singh.	Dg.	33	8·75	Persian wheel.	Do.
53B/16-2B4 .	S. 80°E. of the ridge with a shrine by the west side of G.T. Road near milestone 105 (miles from Delhi) and S.W. of the village Teora at a distance of about one furlong.	Munshi Ram.	Dg.	28	7·25	Persian wheel.	Do.
53B/16-3B1 .	S. 85°E. of the milestone indicating 102 miles to Delhi on G.T. Road and due North of the village Dhantori.	..	Dg.	31	6·66	Persian wheel.	Do.
53B/16-3B2 .	On the Eastern side of the G.T. Road about 80 yds. from the road by the N.W. fringe of the village Khanpur (an extension of the main village situated on the west side of the road).	Shankar Nanua	Dg.	4	4·33	Persian wheel.	Do.

[1]—B—bored ; Dr.—drilled ; Dg.—dug.

[2]—BM—bullocks and mote ; WW—Water wheel ; HC—horizontal centrifugal pump.

DIX 3.

area, Karnal District, Punjab.

Geologic horizon	WATER LEVEL				Use[*]	Temp. (°F)	Remarks.
	Measuring point		Depth to water (ft.)	Date of measurement			
	Description	Above land surface (ft.)					
9	10	11	12	13	14	15	16
Recent and Sub-Recent (Indo-Gangetic alluvium).	Top of the curbing western side of the well.	2·5	18·08	29-1-55	D		Brick and cement lined, water slightly brackish. It is reported water level drops 2 to 3 ft. in summer. Recharge in summer slow after use.
Do.	Top of the curbing south side of the well.	2·25	22·3	29-1-55	I & D		Curbing throughout well. Brick and cement lined, water potable. Works 10 months of the year at the rate of 10 to 12 hours per day. No change in water level reported. Idle at the time of observation. (Crop—wheat, gram, oil seeds, vegetables, etc.
Do.	Top of curbing on the north side of the well.	1·5	21·66	29-1-55	I		Brick and cement lined. Irrigates about 20 bighas (Crop — wheat, gram, sugarcane, oil seeds, vegetables). No change in water level reported. Idle at the time of observation.
Do.	Top of curbing on the eastern side of the well.	3	22·33	29-1-55	I		Brick and cement lined, curbing throughout. Surrounding area specially in the east side shows a topographic low (Lenda *jhil*) and is waterlogged. Soil clayey.
Do.	Top of curbing east side of the well.	2·66	20·5	29-1-55	I & D		Brick and cement lined well curbing throughout. It is reported in summer water level drops about 2 ft. Water potable. Works 10 months of the year, 10 to 12 hours per day.

[*]—D.—domestic ; I—irrigation ; S—stock ; P—public. Un—Uunused or abandoned.

APPEN

Hydrologic Data on Open Wells in the Shahabad-Pipli-Ladwa*

Well No.	Location	Owner	Type¹	Depth (ft.) (below land surface)	Dimension (ft.) Diameter	Method of lift²	Nature of water bearing material
1	2	3	4	5	6	7	8
3B/16-3C6 .	South-Central fringe of the village Jalal-uddin Mazra just north of the village road.	Common village well.	Dg.	24	5·6	..	Sand
53B/16-3C7 .	S. W. fringe of the village Bagrat.	Seni . .	Dg.	22	6	Persian wheel.	Do.
53B/16-3C8 .	On the northern fringe of the village Khairi, N. 30°E. of the ridge in the S.-W. end of the village.	Baktawar Singh Atma Ram.	Dg.	36	8	Persian wheel.	Do.
53B/16-3C9 .	Well located in the New farm house of Col. Surjit Singh. The farm is in the east side of the village, S. 20°W. of village Tatka N. 3°W. of Khari.	Col. Surjit Singh	Dg.	34	..	Pump & Persian wheel.	Do.
53B/16-3C10 .	On the northern fringe of the village Bangran, N. 30°W. of Bodla and N. 82°E. of Untsal.	Munshi Ram Sadhu Ram.	Dg.	24	4·75	Persian wheel.	Do.
53B/16-3C11 .	Located at the site of the abandoned village Muspur, S. 35°E. from the village Bangran S. 45°E. of village Kaulapur and S. 15°E. of Untsal.	Indu Singh Labbu Ram.	Dg.	23	9	..	Do.
53B/16-2B1 .	Near Shahabad, by the side of the G.T. Road near Nitrate factory on the eastern side of the road. About 90ft. S. 75°E. of milestone indicating 107 miles from Delhi.	..	Dg.	30	7·3	Persian wheel.	Do.

DIX 3—*contd.*

a rea, Karnal District, Punjab.

Geologic horizon	WATER LEVEL				Use*	Temp. (°F)	Remarks
	Measuring point		Depth to water (ft.)	Date of measurement			
	Description	Above land surface (ft.)					
9	10	11	12	13	14	15	16
Recent and Sub-Recent (Indo-Gangetic alluvium).	Top of curbing south-eastern side of the well.	2·5	24·08	27-1-55	D		Brick and cement lined. In summer water level drops about 5 ft., reported by villagers. In summer water gives an odour.
Do.	Top of curbing east side of the well.	2·3	22·16	27-1-55	D & I		Curbing throughout.
Do.	Top of curbing S.W. side of the well.	2·75	22·4	27-1-55	I & D		Irrigates about 200 bighas. Works 10 months of the year, 10 to 12 hours per day; continuously for 24 hours when necessary. No change in water level reported during pumping. Water potable.
Do.	Top of curbing on the west side of the well.	1·75	18	22-1-55	I & D		Curbing all throughout. Works 10 to 12 hours per day.
Do.	Top of curbing eastern side of the well.	2·5	19·75	28-1-55	I & D		Irrigates about 60 bighas. Works 10 months of the year, 10 to 12 hours per day. Reported water level drops about 2 to 3 ft. in summer.
Do.	Top of curbing south side of the well.	2	17·6	28-1-55	Un		Brick lined and cement plastered. Well being repaired for future use. Soil loamy.
Do.	Top of curbing north side of the well.	4·17	21·75	29-1-55	I & D		Curbing throughout. Idle at the time of observation. Water potable.

APPEN

Hydrologic Data on Open Wells in the Shahabad-Pipli-Ladwa

Well No.	Location	Owner	Type†	Depth (ft.) (below land surface)	Dimension (ft.) Diameter	Method of lift*	Nature of water bearing material
1	2	3	4	5	6	7	8
53C/13-1C8 .	About 280 ft. north of the milestone 43/4 on the Pipli-Ladwa road and N. 35°W. of the village Mathana.	Sing Ror. .	Dg.	..	7·0	Persian wheel.	Sand
53C/13-1C9 .	On the northern side of the Pipli-Ladwa road about 40 yds. east of the milestone 44.	Roadside Public well.	Dg.	33	7·75	..	Do.
53C/13-1C11 .	N.35°E. of the milestone 45 on Pipli-Ladwa road at a distance of about 120 yds. and due south of the village Shekhpura.	Raja Singh of Shekhpura.	Dg.	28	7·5	Persian wheel.	Do.
53C/13-1C12 .	Due south of Lohana S.35°E. of Girdharpura, about half a mile from the village Sheonti on the west side of the track leading to Girdharpura.	Pratap Singh, Puran Singh, Inder Singh.	Dg.	24	8	Persian wheel.	Do.
53B/16-3C4 .	Due east of Haripur S.75°W. of the pond near the village, at the S.E. fringe of the village.	Chhatar Singh, Harnam Singh, etc.	Dg.	33	7·66	Persian wheel.	Do.
53B/16-3C5 .	South western fringe of the village Lohara.	Sundar Singh.	Dg.	33	7·8	Persian wheel.	Do.

DIX 3—*contd.*

area, Karnal District, Punjab.

Geologic horizon	Water Level				Use[3]	Temp. (°F)	Remarks
	Measuring point		Depth to water (ft.)	Date of measurement			
	Description	Above land surface (ft.)					
9	10	11	12	13	14	15	16
Recent and Sub-recent (Indo-gangetic alluvium).	Top of curbing south side of the well.	3·0	26·8	25-1-55	I		Idle at the time of observation.
Do.	Top of curbing south side of the well.	2·3	27·9	25-1-55	P		
Do.	Top of curbing south side of the well.	1	22·5	26-1-55	I		Irrigates 40 bighas. Works for 10 months of the year, 10 to 12 hours a day. Level drops 2 ft. in summer. Crop—wheat, gram, oil seeds, sugarcane, vegetables. Idle at the time of observation. Water potable.
Do.	Top of curbing south side of the well.	3·66	23	27-1-55	I		Brick and cement lined. Plastered with cement. Curbing throughout. Idle at the time of observation.
Do.	Top of curbing on the S.E. side of the well.	1·5	21·15	27-1-55	I		Brick and cement lined. Curbing throughout. Irrigates about 20 bighas. Water potable. No change in water level reported. Works 10 months of the year, 10 to 12 hours a day. Idle at the time of observation.
Do.	Top of the beam for the Persian wheel. South-western side of the well.	1·75	25·4	27-1-55	I & D		Curbing all throughout. Irrigates about 100 bighas. Works 10 months of the year, 10 to 12 hours a day. Water potable. No substantial change of water level in summer.

APPEN

Hydrologic Data on Open Wells in the Shahabad-Pipli-Ladwa

Well No.	Location	Owner	Type[1]	Depth (ft.) (below land surface)	Dimension (ft.) Diameter	Method of lift[2]	Nature of water bearing material
1	2	3	4	5	6	7	8
53C/13-1C2 .	About 50 yds. due South of milestone 41/1 on the Pipli-Ladwa road.	Baktwar Singh, Kehr Singh, Banta Singh.	Dg.	26	8·25	Persian wheel.	Sand
53C/13-1C3 .	Just at the north eastern corner of the village Sheonti, on the western side of the road leading to Sirdarpura, and west of a small village temple.	Village well.	Dg.	38	8·75	..	Do.
53C/13-1C4 .	N.45°E. of Sheonti and N.30°W. of the milestone 41/5 on the Pipli-Ladwa road and at a distance of 75 yds. (approx.) from the road.	..	Dg.	25	8·6	Persian wheel.	Do.
53C/13-1C5 .	About ¼ mile S. 10°W. of the village Untheri and about 2 furlongs north of the Ladwa-Pipli road ; about a furlong east of the *Kutcha* road leading to the village Untheri.	Amar Singh.	Dg.	33	8·0	Persian wheel.	Do.
53C/13-1C6 .	About 2 furlongs S. S.W. of the Untheri village (N.20°E.). About 100 yds. east of the road leading to Untheri from the Pipli-Ladwa road.	..	Dg.	35	6·6	Persian wheel.	Do.
3 C/13-1C7 .	Just at the north western fringe of the village Untheri; N.45°W. of pond nearby and just north of a village track running along the northern boundary of the village.	Dewan Chand.	Dg.	34	8·15	Persian wheel.	Do.

DIX 3—*contd.*

area, Karnal District Punjab.

Geologic horizon	Water Level				Use*	Temp. (°F)	Remarks
	Measuring point		Depth to water (ft.)	Date of measurement (ft.)			
	Description	Above land surface (ft.)					
9	10	11	12	13	14	15	16
Recent & Sub-Recent (Indo-Gangetic alluvium.)	Top of curbing south side of the well.	3·15	22·3	25-1-55	I		Irrigates about 40 bighas. Works for about 10 months a year, 10 to 12 hours per day. Water potable. Idle at the time of observation. Reported water level drops about 3 to 4 ft. in summer.
Do.	Top of the curbing west side of the well.	2·25	24·9	25-1-55	D		Water is potable.
Do.	Top of the curbing north side of the well.	1·6	21·4	25-1-55	I		Idle at the time of observation.
Do.	Top of curbing on the north side of the well which is at ground level.	0.0	23·75	25-1-55	I		Idle at the time of observation. Soil around clayey, fertile.
Do.	Top of curbing west side of the well which is at ground level.	0·0	25·5	25-1-55	I		Idle at the time of observation.
Do.	Top of curbing north side of the well.	2·5	27·67	25-1-55	I & D		Irrigates about 40 bighas. Works for 10 months of the year. 10 to 12 hours per day. No. change in water level reported. Water potable. Idle at the time of observation.

APPEN

Hydrologic Data on Open Wells in the Sahabad-Pipli-Ladwa

Well No.	Location	Owner	Type¹	Depth (ft.) (below land surface)	Dimension (ft.) Diameter	Method of lift²	Nature of water bearing material
1	-	3	4	5	6	7	8
53B/16-3C1 .	Just at the south-eastern fringe of the village Bodla. S. 80°W. of a nearby pond and just west side of a road leading to village Tatki.	Babu Ram Maru Ram, etc.	Dg.	35	9·4	Persian wheel.	Sand.
53B/16-3C2 .	S.30°E. of the village Chharpura, just on the east side of the main village road at the fringe of the village.	Chhaju, Sarda etc.	Dg.	35	10·5	Persian wheel.	Do.
53B/16-3C3	South-eastern fringe of the village Mukarpur, just on the south-eastern bank of a small pond and occurs between a banyan and pipal tree.	Mom Raj Lala, Ram, etc.	Dg.	34	9·7	Persian wheel.	Do.
53C/13-1C10 .	About 150 yds. S. 20°E. of a nearby pond and N.20°E. of a *pucca* building in the village of Shekhpur.	Village well.	Dg .	31	5·8	..	Do.
53G/1-1A1	About 50 yds. due north of the milestone 38/3 on the Pipli-Ladwa road.	Not known.	Dg.	32	8·25	Persian wheel.	Do.
53C/13-1C1 .	120 yds. due south of milestone 40/7 on the Pipli-Ladwa road. About a furlong west of a new refugee village Singhmajra.	Indra Singh Tota Singh Boga Singh.	Dg.	29	7·25	Persian wheel.	Do.

DIX 3—*contd.*

area, Karnal District, Punjab.

Geologic horizon	Water Level				Use*	Temp. (°F)	Remarks
	Measuring point		Depth to water (ft.)	Date of measurement			
	Description	Above land surface (ft.)					
9	10	11	12	13	14	15	16
Recent & Sub-Recent (Indo-Gangetic alluvium).	Top of the curbing north side of the well.	3·58	22·0	23-1-55	I & D		
Do.	Top of curbing north side of the well.	2·5	24·08	23-1-55	I & D		Irrigates about 60 bighas. Works for 10 months a year, 17 hours per day. No change in water level reported since last 20 to 30 years. Idle at the time of observation.
Do.	Top of curbing north side of the well.	1·5	28·6	23-1-55	I		Irrigates about 160 bighas. Crop-wheat sugar cane, oil seeds, vegetables, gram, etc. Works for 10 months a year, 10 to 12 hours per day. No change in water level reported since last 20 to 30 years. Water potable. Idle at the time of observation.
Do.	Top of curbing south side of the well.	3·2	27·9	23-1-55	D		
Do.	Top of curbing north side of of the well.	2·15	22·0	25-1-55	I		Crop-wheat, gram, oil seeds, sugarcane, vegetable, etc. Idle at the time of observation.
Do.	Top of curbing south-eastern side of the well.	1·5	19·8	25-1-55	I		Irrigates about 300 bighas. Works for 10 months a year, 10 to 12 hours per day. No change in water level reported. Water potable. Idle at the time of observation.

APPEN

7

Hydrologic Data on Open Wells in the Shahabad-Pipli-Ladwa

Well No.	Location	Owner	Type[1]	Depth (ft.) (below land surface)	Dimension (ft.) Diameter	Method of lift[2]	Nature of water bearing material
1	2	3	4	5	6	7	8
53B/16-3B8 .	On the N. side of the village 20 yds. north of the pond and N.75°W. of Murthala village Dudla.	..	Dg.	30	8·66 at top.	Persian wheel.	Sand
53C/13-1B4 .	S.85°E. of Southern corner of the pond west of village Umri, just south of the road running in the southern fringe of the village N. 20°W. of nearby pond.	Balak Ram, Mamraj, Harnam.	Dg.	45	9·75	Persian wheel.	Do.
53C/13-1C19 .	Due S. of T.W. 45 (¼ mile from it) S. 82° W. of Bodhi (about 1/2 and S. 70°E. of Umri.)	Chatru . .	Dg.	37	7·66	Persian wheel.	Do.
53C/13-1C20 .	At N.E. fringe of the village just N. of the village N. 85°E. of a Sikh temple.	Chamaruvala.	Dg.	37	7·6	Persian wheel.	Do.
53C/13-1C18 .	N.35°E. of T.W. 45. N.20°W. of Bodhi about a mile from it.	Kesar Singh of Keshingarh.	Dg.	37	8·0	Persian wheel.	Do.
53C/13-1B2 .	N.45°E. of Pipli and N.35°W. of fort in Bazidpur at the N. W. fringe of the village west of a pond.	Inder Singh.	Dg.	27	6·66	Persian wheel.	Do.
53C/13-1B3 .	At the eastern fringe of the village Baholi north of the pond.	..	Dg.	29	7·16	Persian wheel.	Do.
53C/13-1B1 .	S.30°E. of M/S 95 about 70 ft. east of the G.T. Road.	Not known.	Dg.	34·66	9·56	Persian wheel.	Do.
53B/16-3B3 .	130 ft. south of M/S 97 eastern fringe of the G.T. Road.	P.W.D. well.	Dg.	25	10:25	Persian wheel.	Do.

DIX 3—*contd.*

area, Karnal District, Punjab.

Geologic horizon	Water Level				Use*	Temp. (°F)	Remark
	Measuring point		Depth to water (ft.)	Date of measurement			
	Description	Above land surface (ft.)					
9	10	11	12	13	14	15	16
Recent & Sub-Recent (Indo-Gangetic alluvium).	Top of curbing E. of the well.	2·66	26	30-1-55	D & I		Brick lined.
Do.	Top of curbing N.W. side.	2·91	26·16	4-2-55	D		
Do.	Top of curbing N. side.	1.83	83·68	6-2-55	I		Curbing throughout, brick lined.
Do.	Top of curbing E. side.	1·33	26·0	6-2-55	D		Curbing throughout.
Do.	Top of a wooden beam on western side.	2·00	25·33	6-2-55	I		Curbing broken. No change in water level reported.
Do.	Top of curbing S.30°E. of the well.	2·25	21·25	30-1-55	D & I		Curbing throughout, brick lined. Water reported to be good also that water level drops one foot in summer.
Do.	Top of curbing south side of the well.	2·58	22·16	30-1-55	D & I		Curbing throughout brick lined. No change in water level during summer reported.
Do.	Top of curbing S.W. of the well.	0·0	24·25	30-1-55	D		Curbing throughout, brick lined.
Do.	Top of curbing N. side of the well.	3·0	22·5	30-1-55			Curbing appears to be throughout. Brick lined. Comented up to 8 ft. below.

APPEN

Hydrologic Data on Open Wells in the Shahabad-Pipli-Ladwa

Well No.	Location	Owner	Type[1]	Depth (ft.) (below land surface)	Dimension (ft.) Diameter	Method of lift[2]	Nature of water bearing material
1	2	3	4	5	6	7	8
53B/16-3B4 .	S.80°E. of village Ramgarh about 100 yds. from it.	Phula, Sarda.	Dg.	22	9·66	Persian wheel.	Sand
53B/16-3B5 .	About two furlongs N.50°E. of Isangarh and S.15°W. of Kaulapur and 100 ft. east of the road leading to Kaulapur.	Bachhan Singh.	Dg.	36	8·50	Persian wheel.	Do.
53B/16-3C12 .	S.85°W. of Begram and S.75°E. of Kaulapur at the N.W. Corner of the village.	Banawari-Lambadur.	Dg.	28	8·0	Persian wheel.	Do.
53B/16-3B6 .	S.30°E. of Kaulapur and N.85° west of Untsal about 80 yds. east of the village road leading to Murthala under a banyan tree.	Tulsi, Ayan, etc.	Dg.	36	8·66	Persian wheel.	Do.
53B/16-3C18 .	S.70°W. of the village Rampur and S.75°E. of Murthala and N.25°W. of the village Narchahri N.W. of a small pond.	Badwarmal .	Dg.	42	8·33	..	Do.
53B/16-3C14 .	S.60°W. of village Kasital N.85°E. of Murthala and about 50 yds. west of the village road.	Santa Singh .	Dg.	32	7·00	Persian wheel.	Do.
53B/16-3C15 .	S.30°E. of Rampur and about one furlong N.30°W. of Kasital and about 100 ft. west of the road leading to Ramnagar.	Ram Singh .	Dg.	32	8·00	Persian wheel.	Do.
53B/16-3C16 .	S.35°E. of the village Ramnagar about a furlong from the village and due E. of Kalal Mazra.	Village well .	Dg.	32	8·00	..	Do.

DIX 3—*contd.*

area, Karnal District, Punjab.

Geologic horizon	Water Level				Use*	Temp. (°F)	Remarks
	Measuring point		Depth to water (ft.)	Date of measurement			
	Description	Above land surface (ft.)					
9	10	11	12	13	14	15	16
Recent & Sub-Recent (Indo Gangetic alluvium).	Top of curbing E. side.	2·75	15·75	30-1-55	D & I		Water reported to be good, also that level goes down by 1 or 2 ft. during summer.
Do.	Top of curbing S. side of the well.	2·16	19·25	30-1-55	I		Curbing throughout, brick lined, cement plastered.
Do.	Top of curbing N. side of the well.	3·4	24·08	30-1-55	I & D		Curbing throughout, brick lined.
Do	Top of curbing N. side of the well.	2·33	27·0	30-1-55	I		Curbing throughout, brick lined.
Do.	Top of curbing N. of the well.	5·3	28·75	30-1-55	D & I		
Do.	Top of curbing S. of the well.	2·66	25·58	30-1-55	..		Curbing throughout, brick lined, cement plastered.
Do.	Top of curbing S.W. of the well.	2·25	27·16	30-1-55	..		Curbing throughout, cement plastered.
Do.	Top of curbing S.W. of well.	1·50	25·0	30-1-55	D & I		Curbing throughout brick lined.

Hydrologic Data on Open Wells in the Shahabad-Pipli-Ladwa

Well No.	Location	Owner	Type[1]	Depth (ft.) (below land surface)	Dimension (ft.) Diameter	Method of lift[2]	Nature of water bearing material
1	2	3	4	5	6	7	8
5 3B/16-3C17 .	S.60°E. of Kalal Mazra S.80°W. of Ramnagar and about 30 yds. E. of pond situated at the east of the village near a pipal tree.	Naihala, Siboo, etc.	Dg.	36	7·66	Persian wheel.	Sand
53B/16-3B7 .	N.E. corner of the village Morthala N.W. of the pond S.70°W. of Machhuri just east of road leading to Jalkheri.	..	Dg.	37	6·33	Persian wheel.	Do.
53C/13-1C-17	S.10°E. of ridge N. of Daulatpur, S.35°W. of the village Mathana at the N.W. fringe of village.	Ranjit Singh.	Dg.	37	8·25	Persian wheel.	Do.
53C/13/1C21 .	N.E. fringe of the village Kheri Gaderi S.20°W. of Kurami N.25°E. of T.W. 33 and ¼ mile N.E. of Bodhi.	Chandan Singh Ratan Singh.	Dg.	47	8·05	Persian wheel.	Do.
53C/13-1C22 .	S.55°W. of Godla S.30°W. of the temple near the village in the western corner of the pond.	Kher Singh, Nanni.	Dg.	37	8·25	Persian wheel.	Do.
53C/13-1C23 .	Inside the compound of the village Gurudwara which is situated by the side of the pond on the western fringe of the village.	..	Dg.	32	3·92	Persian wheel.	Do.
53G/1-1A3 .	N.40°S. just north of the M/S 37/3 south.	..	Dg.	38	9·75	Persian wheel.	Do.
53B/4-3A1 .	Just north of an elevated ground N.10°W. of Ladwa about a furlong East of Ladwa-Shahbaad Road-S.40°W. of Bakali and S.70°W. of Kheri.	Ragbir Saran .	Dg.	24	7·33	Persian wheel.	Do.

DIX 3—*contd.*

area, Karnal District, Punjab.

Geologic horizon	Water Level				Use*	Temp. (°F)	Remarks
	Measuring point		Depth to water (ft.)	Date of measurement			
	Description	Above land surface (ft.)					
9	10	11	12	13	14	15	16
Recent and Sub-Recent Indo-Gangetic Alluvium.	Top of curbing W. side.	3·00	26·0	30-1-55	D & I		
Do.	Top of curbing W. of the well.	2·5	32·66	30-1-55	D & I		Brick lined.
Do.	Top of curbing N. side of the well.	1·23	27·75	6-2-55	I & D		Curbing throughout, brick lined.
Do.	Top of curbing S. of the beam.	0·75	23·86	7-2-55	I & D		Curbing throughout.
Do.	Top of curbing S. E. side of the well.	2·00	26·58	7-2-55	I & D		Water level drops in summer by about 2 ft. (reported).
Do.	Top of curbing S. E. of the well.	1·5	25·16	..	D		Curbing throughout, brick lined.
Do.	Top of broken curbing on the east side.	2·33	20·33	8-2-55	I		Loamy soil.
Do.	Top of curbing N. W. side.	5·16	22·25	8-2-55	I		

APPEN

Hydrologic Data on Open Wells in the Shahabad-Pipli-Ladwa

Well No.	Location	Owner	Type[1]	Depth (ft.) (below land surface)	Dimension (ft.) Diameter	Method of lift[2]	Nature of water bearing material
1	2	3	4	5	6	7	8
53C/1-1A2 .	Temple well on the N. side of Ladwa-Pipli road on the western bank of a pond near the M/S 3B.	..	Dg.	35	7·5	H.C.	Sand
53C/13-1C13 .	Just South of M/S 42/3 on the Ladwa-Pipli road, south side of the road inside a compound.	Bishnu Swarup	Dg.	29	6·0	H.C.	Do.
53C/13-7C15 .	About 200 feet S.W. of a temple situated in the western bank of a pond at the north-western corner of village Mathana.	Village well .	Dg.	33	6·82	Persian wheel.	Do.
53C/13-1C14 .	S.15°W. of M/S 43/4 on the Pipli-Ladwa road. About 1 furlong from the road.	Surjbhan of Mathana.	Dg.	34	8·0	Persian wheel.	Do.
53C/13-1C16 .	Just N.60°E. of a village school, at the eastern part of the village Sisma.	Not known .	Dg.	33	7·5	Persian wheel.	Do.
53F/4-3A2 .	S.30°E. of Bhalasi and S.75°W. of Bhakald, about a furlong E. of the Ladwa-Shahabad road.	Sunder of Dhananra.	Dg.	31	7·0	Persian wheel.	Do.
53F/4-3A3 .	S. 25°E. of Bhalari near a banyan tree and south of a village track.	Rasalal . .	Dg.	36	7·0	Persian wheel.	Do.
53F/4-3A4 .	At the south-western fringe of Bhalari.	Pyralal . .	Dg.	32	10·5	Persian wheel.	Do.
53F/4-3A5 .	....	Indu, Ramdhan etc.	Dg.		6·25	Persian wheel.	Do.
53F/4-3A10 .	Just at the north-eastern fringe of Nawari about 50 yds. south of a pond.	Village well .	Dg.	35	6·2	Persian wheel.	Do.

DIX 3—*contd.*

area, Karnal District, Punjab.

Geologic horizon	Water Level				Use[3]	Temp. (°F)	Remarks.
	Measuring point		Depth to water (ft.)	Date of measurement.			
	Description	Above land surface (ft.)					
9	10	11	12	13	14	15	16
Recent and Sub-Recent (Indo-Gangetic alluvium).	Top of curbing N. of the well.	2·41	21·66	8-2-55	D		Fitted with hand pump. Water is potable.
Do. .	Top of curbing E. side of the well.	2·66	22·33	8-2-55	D		Fitted with a hand pump.
Do. .	Top of the slab on the north-eastern side.	2·33	25·16	8-2-55	D		Water is potable.
Do. .	Top of curbing west side.	2·66	27·08	8-2-55	D & I		Idle at the time of observation; irrigates about 150 bighas.
Do. .	Top of curbing west side.	1·5	23·91	8-2-55	D & I		The well irrigates about 60 bighas.
Do. .	Top of curbing east side.	1·10	21·5	10-2-55	I		
Do. .	Top of the wooden beam on the N.W. side of the well.	0·0	23·5	10-2-55	I & D		Irrigates about 400 bighas. Water level goes by 4 to 6 ft. during summer.
Do. .	Top curbing on the north-east side.	0·66	24·11	10-2-52	I & D		The well irrigates about 80 bighas.
Do. .	Top of curbing west side.	2·25	25·33	10-2-55	I		The well irrigates about 100 bighas.
Do. .	Top of curbing south side.	3·10	30·8	10-2-55	D		

Hydrologic Data on Open Wells in the Shahabad-Pipli-Ladwa

Well No.	Location	Owner	Type[1]	Depth (ft.) (below land surface)	Dimension (ft.) Diameter	Method of lift[*]	Nature of water bearing material
1	2	3	4	5	6	7	8
53F/4-3A6	At the eastern fringe of the Rurki, west of a village road leading to Phaladpur.	Jagat Singh Hawaldar.	Dg.	33·4	7·3	Persian wheel.	Sand
53F/4-3A8	At the western fringe of Phaladpur, and south-west of a pond.	Ajmer Singh Nambardar, Ganda, Phagu etc.	Dg.	31	8·0	Persian wheel.	Do.
53F/4-3A7	West of Bholapur, about 70 feet west of culvert of the Ladwa-Sahabad road.	Dagaram, Nathu etc.	Dg.	28	6·25	Persian wheel.	Do.
53F/4-3A9	S.85°E. of the village Baini, just west of the Ladwa-Sahabad road (temple road).	Public well	Dg.	25	9·66	Persian wheel.	Do.
53B/163C22	N.10°E. of Gohana, about 100 yards west of the Ladwa-Sahabad road. Just east of the road to Gohana.	Jagu Nambardar	Dg.	27	9·1	Persian wheel.	Do.
53B/16-3C21	About a furlong S.50°W. of a culvert on the Ladwa-Sahabad road at the eastern fringe of the village Babal.	Public well	Dg.	23	6·4	Persian wheel.	Do.
53B/16-3C20	North eastern corner of Bihat, and S.60°W. of Babain.	Sadi	Dg.	31	8·0	Persian wheel.	Do.
53B/16 4C19	S.30°W. of Hamidpur, N.60°W. of a temple near Babain.	Sitaram, Baburam, Bijlal, etc.	Dg.	32	7·0	Persian wheel.	Do.

DIX 3—*contd.*

area, Karnal District, Punjab.

Geologic horizon	WATER LEAVEL				Use[3]	Temp. (°F)	Remarks
	Measuring point						
	Description	Above land surface	Depth to water (ft.)	Date of measurement			
9	10	11	12	13	14	15	16
Recent and Sub-Recent Inds-Gangetic alluvium.	Top of curbing west side of the well.	0·0	26·0	11-2-55	I & D	..	The well irrigates about 160 bighas. Idle during observation.
Do.	Top of curbing south side.	2·25	24·9	11-2-55	I & D		The well irrigates about 80 bighas; fitted with Persian wheels. Land is not fertile. Idle during observation.
Do.	Top of curbing north side.	2·16	25·16	11-2-55	D		Water is potable.
Do.	Top of curbing east side.	2·5	20·08	11-2-55	D		Water is potable.
Do.	Top of curbing west side.	2·8	20·8	11-2-55	I		Irrigates about 100 bighas. Works for 10 months @ 10 hours a day. Idle during observation. Water is potable.
Do.	Top of curbing north side of the well.	4·0	23·08	11-2-55	D		Water is potable.
Do.	Top of curbing east side of the well.	2·4	22·66	11-2-55	I		Irrigates about 55 bighas. Works for 10 months @ 12 hours a day. Crop—wheat, gram, potatoes, oil seeds etc. Water is potable.
Do.	Top of curbing west side of the well.	2·4	26·8	11-2-55	I		The well irrigates about 60 bighas. It works for 10 months @ 12 hours a day. Water is potable.

APPEN

Hydrologic Data on Open Wells in the Shahabad-Pipli-Ladwa

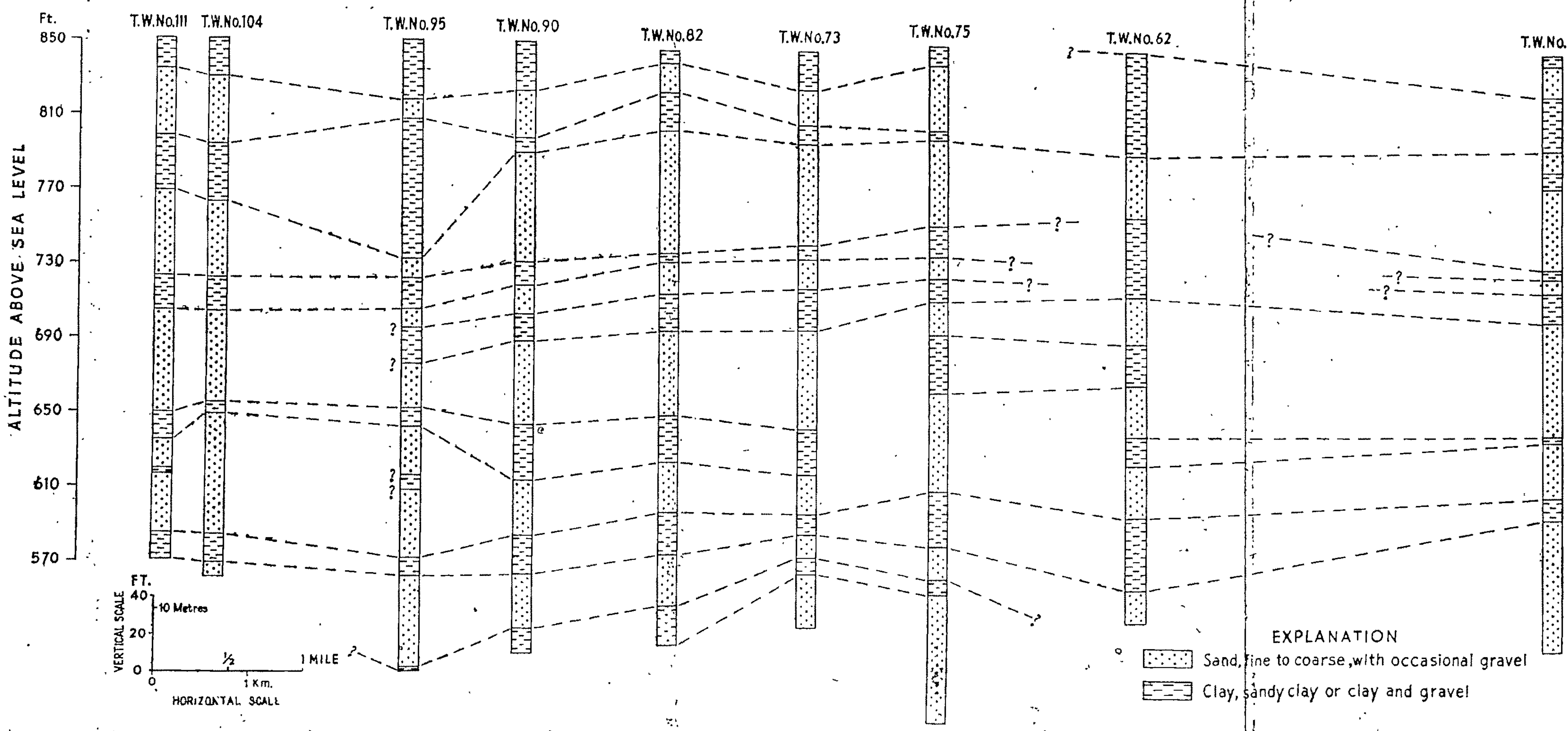
Well No.	Location	Owner	Type[1]	Depth (ft.) (below land surface)	Dimension (ft.) Diameter	Method of lift[2]	Nature of water bearing material
1	2	3	4	5	6	7	8
53B/16-2C1 .	S.15°W. of Haripur just on the western side of the Ladwa, Sahabad road.	..	Dg.	26	5·08	Persian wheel.	Sand
53B/16-2C2 .	At the southern corner of Syra; about 30 yards N.75°W. of a village Gudwara.	Bata Singh, Pala Singh, etc.	Dg.	32	8·4	Persian wheel.	Do.
53B/16-3C18 .	At the southeastern corner of the village Mandhokra, about 120 feet north of a pond.	Kartar Singh, Natta Singh, etc.	Dg.	32	7·4	Persian wheel.	Do.
53B/16-2C3 .	N.W. of the village Naraingarh, about 60 feet east of the Ladwa-Sahabad road.	Jamu Singh.	Dg.	27	4·25	Persian wheel.	Do.
53B/16-2C4 .	At the eastern fringe of Kharindwa, north of a village temple.	Public well .	Dg.	33	9·0	Persian wheel.	Do.
53B/16-2B8 .	At the east Central fringe of the village Machrauli; about N.75°W. of a pond.	Public well .	Dg.	29	10·58	Persian wheel.	Do.
53B/16-2B7 .	At the estern fringe of the village Dig.	Bole Chand and Rajaram Nambardar.	Dg.	30	9·16	Persian wheel.	Do.
53B/16-2B5 .	About 100 yds. S. 70°W. of Chhapri.	Rameswar Joyram, etc.	Dg.	30	8·0	Persian wheel.	Do.
53B/16-2B6 .	About 80 ft. east of a temple east of a foot track in the Chhapri.	Village well .	Dg.	26	7·33	Persian wheel.	Do.
53B/16-2B9 .	About 140 ft. north of the milestone No. 17 on the Ladwa-Sahabad road, west of the road.	Bachan Singh .	Dg.	30	7·0	Persian wheel.	Do.

DIX 3—*contd.*

area, Karnal District, Punjab.

Geologic horizon	Water Level: Measuring point: Description	Water Level: Measuring point: Above land surface (ft.)	Water Level: Depth to water (ft.)	Water Level: Date of measurement	Use*	Temp. (°F)	Remarks
9	10	11	12	13	14	15	16
Recent and Sub-Recent (Indo-Gangetic alluvium).	Top of curbing west side of the well.	3·33	26·58	11-2-55	I & D		
Do.	Top of curbing N. E. side of the well.	3·75	27·58	12-2-55	D		The well irrigates about 300 bighas, it works for 10 months @ 12 hours a day.
Do.	Top of curbing west side of the well.	2·6	27·33	12-2-55	I & D		Irrigates about 125 bighas. The well works for 10 months, 12 hours a day. Water is potable. Idle during observation.
Do.	Top of curbing N.W. side of the well.	2·6	24·66	12-2-55	D		Water potable.
Do.	Top of curbing south side of the well.	4·8	27·0	12-2-55	I & D		The well irrigates about 75 bighas.
Do.	Top of curbing south side of the well.	2·0	23·08	12-2-55	D		
Do.	Top of curbing north side of the well.	2·16	22·58	12-2-55	I & D		Irrigated about 60 bighas. Idle during observation.
Do.	Top of curbing east side of the well.	2·16	20·08	12-2-55	I & D		Irrigates about 75 bighas.
Do.	Top of curbing south side of the well.	4·8	23·75	12-2-55	D		Water is potable.
Do.	Top of the curbing on the east side of the well.	1·33	21·0	12-2-55	I & D		The well irrigates about 50 bighas. The water is potable.

NORTH-SOUTH GENERALISED GEOLOGICAL SECTION A-A', IN THE SHAHABAD-PIPLI-LADWA AREA

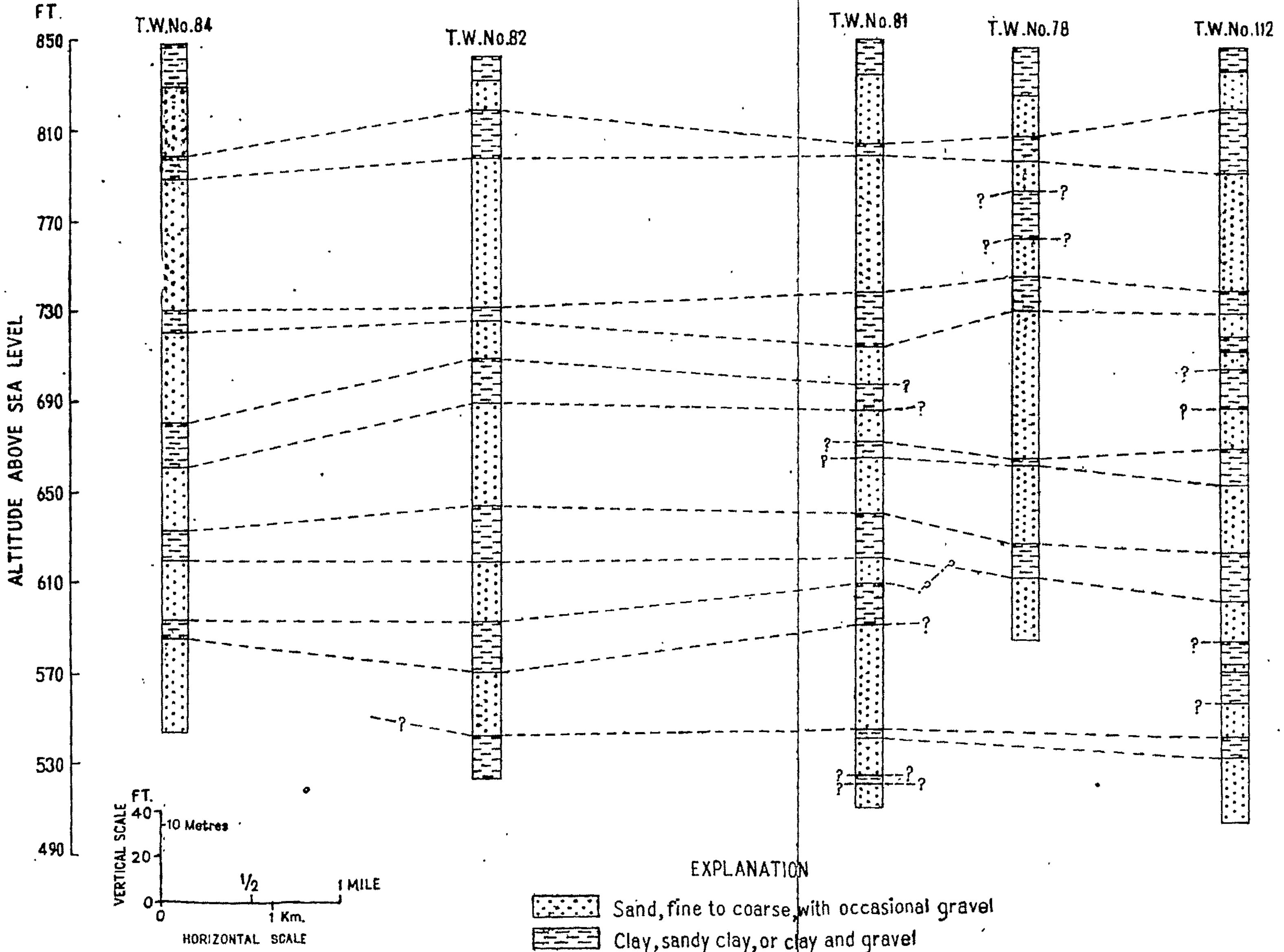


G. S. I., Calcutta.

GEOLOGICAL SURVEY OF INDIA

Bull. Ser. B, No. 14, Pl. 4

EAST-WEST GENERALISED GEOLOGICAL SECTION B-B′ IN THE SHAHABAD-PIPLI-LADWA AREA



EXPLANATION

- ⛆ Sand, fine to coarse, with occasional gravel
- ▤ Clay, sandy clay, or clay and gravel

G. S. I., Calcutta.

PART I—GENERAL

I. INTRODUCTION

The Ministry of Natural Resources and Scientific Research decided to carry out sampling of the Majhgawan Diamond deposit in the Panna district, Madhya Pradesh, for assessing its potential value and reserves. The geological work including the planning of the sampling procedure was conducted by the Geological Survey of India, while the sinking of the sampling shafts was entrusted to the Indian Bureau of Mines. The supervision of the sampling and milling work was made jointly with the Indian Bureau of Mines.

Most of the Majhgawan pipe area is leased out to the Panna Diamond Mining Syndicate Limited, and a small portion is under the lease of Shri Suresh Chandra Sharma of. the Mahalakshmi Diamond Mining Works, and it is now understood to have been taken over by the Syndicate. Only the Syndicate was exploiting the deposit.[1]

Earlier Background of the Work.—Under the guidance and instructions of Shri V. P. Sondhi, Director, Geological Survey of India, and advice of Mr. J. A. Straczek of the United States Geological Survey, on deputation to the Geological Survey of India, it was decided to draw a grid of lines 250 ft. apart on the existing plan of the Majhgawan pipe, made by the senior author in 1952 (Mathur, 1953, p. 40) and to locate the sampling pits at the intersections of the lines. Since some of the intersections fell just beyond the pipe limit, the positions of such pits were shifted slightly and brought within the pipe area. This gave a total of 21 pits. It was decided to dig open pits of 30 ft. × 10 ft. size and take out 100 tons of the "agglomeratic tuff" from each pit for sampling. One such pit was started in the middle of November, 1955.

Russian Experts.—Mr. B. Breshenkov, Geologist and Mining Engineer, and Mr. G. F. Shevtsov, ore dressing Engineer, were invited by the Government of India from the U.S.S.R. to advise on the development of the Panna diamond mines. They arrived at Panna on the 15th December, 1955, and left on the 4th February, 1956. They devoted their attention mainly to the sampling operations at Majhgawan. They also made short study trips to other mining centres in the field and places of geological interest nearby. Mr. Gribin, leader of the Soviet Mining Group, came to Panna with the other Russian Experts on the 15th December, 1955, and spent a few days. He revisited Panna on two subsequent occasions.

When the Russian experts visited Panna in the middle of December, 1955, they proposed a change in the type of pits to be dug. They suggested that instead of digging trenches for obtaining 100 ton samples, shafts measuring 8 ft. × 6 ft. may be sunk to obtain 40-ton samples. This change was suggested so as to complete the work in three months —the period of the Russian delegation's stay in India.

---

[1] Since this report was written, the lease of the Syndicate has been terminated and the property is now within the Prospecting Licence area of the National Mineral Development Corporation Limited, Diamond Mining Project.

This scheme was followed until the middle of March, 1956, when Dr. M. S. Krishnan, Officer on Special Duty in the Ministry of Natural Resources and Scientific Research, visited the mine. He observed that this scheme would take an unduly long time to accomplish, because the solid "agglomeratic tuff" was found in some of the shafts at very great depth, and suggested that the weathered pipe rock in the deeper pits should be sampled without attempting to obtain the fresh, compact "agglomeratic tuff". Except for one complete and one partial alluvial overburden sample, others could not be beneficiated, because the rains damaged the samples and there was no time left to treat them. Some shafts could not be completed because of lack of time due to the onset of the monsoon. One pit on the grid could not be started at all, because its position fell in the water-filled Bharakan pit.

Preparation of Large Scale Maps.—A map on the scale of one inch= 50 ft. of the Majhgawan diamond deposit was prepared by theodolite survey giving all the natural as well as man-made details with contour interval of 2½ ft. This map has been reduced to the scale of one inch= 100 ft. and forms Plate 6 of this Bulletin. Since no Survey of India Bench Mark existed anywhere near the area, a datum of 100 was arbitrarily chosen at the corner of a building near the rectangular well. All contours and Reduced levels on the map are with reference to this point. The spot is now marked with a cement concrete pillar with the following inscription at the top : B.M./100/G.S.I. In addition, a geological map (scale one inch=50 ft.) of the deposit was prepared with plane-table by Shri N. A. Vemban, Geologist and Sarvashri Y. Balasankaram and M. G. Rao, Assistant Geologists, Geological Survey of India during January, 1956.

Location and Communications.—Majhgawan lies almost at the western extremity of the known diamond-producing belt in the Madhya Pradesh region, at a distance of about 14 miles by road from Panna, the district headquarters. The first five miles of the route from Panna are along the main road to Chhatrapur. From mile 51 of this road, a private road goes up to the mine. This road is negotiable by jeep even during the monsoons, but for a few *nalas* that halt traffic temporarily when a sudden flood after heavy rains stops all crossings.

Panna is situated on the trunk road that connects the railway stations Satna and Manikpur and passes through the heart of the Vindhya Pradesh region of the new Madhya Pradesh State. Panna to Satna is a distance of about 45 miles, and regular service buses ply along this route. Jhansi railway station is about 120 miles from Panna.

Physical Features.—The Majhgawan diamond deposit is situated on the long and narrow tableland formed by the Kaimur sandstone that stretches in a north-east to south-west direction. Along the north-west it ends abruptly in a steep scarp, 350 to 400 ft. high, overlooking the Bundelkhand plain. This scarp is deeply dissected by narrow gorges which are three to six miles long. To the south-east the Rewa plateau rises again in a 250 to 300 ft. high scarp in the form of a gigantic step. This is also separated by narrow gorges, but they are only a mile or two long and not as big as those cutting through the Kaimurs.

The Kaimur tableland is more or less an undulating plain with a few low hills scattered here and here. Numerouss haollw treams flow towards north-west and terminate at the heads of the gorges. They remain practically dry except during the monsoon when they act as run-off channels for rain water.

Acknowledgements.—We are very thankful to the Russian experts for their advice. We would like to express indebtedness to Dr. M. S. Krishnan, Officer on Special Duty in the Ministry of Natural Resources and Scientific Research (now retired), for discussions on several important problems connected with this investigation. We are very grateful to Shri V. P. Sondhi, Director of Geological Survey of India, (since retired) for his keen interest and constant encouragement. To Dr. B. C. Roy, Superintending Geologist-in-charge, Economic Geology Section (now Director General) and to Dr. A.G. Jhingran, Superintending Geologist of the Northern Circle (now Director, Eastern Region), G.S.I., we are obliged for their valuable suggestions.

We have also to record our thanks to our colleagues in the Geological Survey, Indian Bureau of Mines and the Panna Diamond Mining Syndicate Limited who co-operated during the course of this investigation. Grateful thanks are also due to Shri P. L. Jadia, Diamond Officer, for assistance at all times. Shri M. G. Kulkarni, Managing Agent of the Syndicate, gave us all help and we are thankful to him.

PART II—GEOLOGY

II. REGIONAL GEOLOGY AND CONTACT EFFECTS

The Majhgawan pipe is surrounded on all sides by the Kaimur Sandstone and is considered as intrusive into it. The geological formations met with in this region are given below :

Alluvium		
Laterite		
Deccan Trap (?)		
Lameta Sandstone (?)		
Vindhyan System	Rewa Series	Upper Rewa Sandstone Jhiri Shale
	Kaimur Series	Sandstone Conglomerate
	Semri Series	Palkua Shale Limestone Sandstone Quartzites, Shale
Bijawar Series		Jaspers and Conglomerates
Bundelkhand Granite.		

The Kaimur sandstone and the formation below it have some bearing on the pipe as it passes through them and is also in some measure affected by them. It is natural to expect that inclusions of these rocks would be found in the matrix of the volcanic pipe rock. The overlying Jhiri shale also appears to have played some part in the history of the pipe, as it is believed that it possibly filled the under part of the basin to some extent.

The query marks against the Deccan Trap and Lameta Sandstone have been made to indicate that the authors doubt the correctness of these identifications made by the earlier workers and accepted so far. The small isolated masses of trap found so far away from the main outcrop of the Deccan Trap occur in a line roughly parallel to the edge of the Rewa scarp and nowhere else on the Rewa plateau. This and their occurrence at a much lower level than the main outcrop suggest that a reassessment of their geological position is desirable. They are most probably intrusive dolerites.

Kaimur Sandstone.—This formation is of particular interest since it encloses the pipe. Willson's geological map of 1873-77 distinguishes two horizons, an upper and a lower. The basis for this division is not clear and in the opinion of the present authors, it is considered advisable to group them together unless detailed re-mapping proves a justification for Willson's view (see Vredenburg, 1906, p. 267).

The sandstone surrounding the pipe is actually an orthoquartzite, is fine-grained, of white or sometimes greyish colour, and quite compact. Upon weathering it disintegrates into granular lumps and becomes quite soft. This formation sometimes contains intercalated beds of shales which are greyish green and occasionally reddish in colour.

Under the microscope the quartz grains are seen to be almost equigranular, and the vast majority are rounded to sub-rounded with a very few angular to sub-angular ones. They are bonded by siliceous material or by secondary authigenic silica. A small number of grains appear to be of chalcedony which shows aggregate structure. Minor amounts of felspar, muscovite mica and epidote are also found. Hematite occurs as cement and as patches and veins.

The shales found as intercalations within the Kaimur sandstone horizon are very fine-grained and somewhat sandy. Grains of felspar, quartz, mica and some epidote studding the groundmass, can be recognised under the microscope. These appear to be different from the Jhiri shales, which do not generally contain such grains, and the grains if present are very few in number and smaller in size.

The rock is also charged heavily with ferruginous matter which forms irregular streaks and patches, and sometimes occurs as detrital grains. A green material is also observed which between crossed nicols shows aggregate texture. Its exact nature could not be determined, but it appears to be chlorite.

Contact Rock.—An actual contact of the ultramafic pipe rock with the country rock of sandstone has nowhere been seen so far. However, in some sampling shafts, which appear to be close to the pipe boundary, the sandstone and its associated shales show some peculiar features. The shafts which are believed to be near the pipe boundary and affected to some extent thereby are Nos. 7 and 18.

Below the alluvial cover in shaft No. 7 there is a 15 ft. thick brown and yellow coloured sandy rock which shows rough foliation. Owing to this structure the Russians took it to be ferruginated " agglomeratic tuff ". A microscopic study, however, showed that it is an arenaceous sediment that has been metamorphosed and altered in a peculiar manner. It consists mostly of a groundmass of a brownish substance which appears to be a clayey matter stained with limonite. Studded as specks in this mass are minute grains of chalcedony, and larger grains and aggregates of quartz that show undulose extinction indicative of strain. Occasionally, larger twinned crystals of orthoclase are also seen.

Some interesting disturbance of the sandstone and its associated shales has taken place and is seen in shaft No. 18. The rocks have been crumpled and sheared, although on a small scale, possibly because of the pressure exerted by the magmatic material. The shales have been shattered into sub-angular to sub-rounded blocks and have been mixed with similar blocks of the siliceous rock. A few thin veins of white and flesh coloured quartz intrude through the disturbed country rock. Scattered specks and patches of pyrite up to six inches across are present in the veins. These veins possibly represent the last phase of the magmatic activity.

The siliceous rock from this shaft is similar in appearance to that from shaft No. 7. Under the microscope, however, more translucent, brown clayey matter is seen in it. Larger spherulitic masses of chalcedony showing aggregate structure are scattered throughout the groundmass. A very unusual and interesting mineral found in the thin sections of this rock is dolomite which shows good crystal outlines and perfect zonal structure. Calcite is also present in subordinate quantities.

Discussion on Contact Effects.—As mentioned earlier actual contact has not been seen anywhere so far. Possibly the only definite boundary of the pipe is seen in the sloping wall of sandstone exposed in Bharakan, but the contact with the ultramafic pipe rock is not seen. This sandstone is free from any structural deformity and thermal effect. On the other hand, the structural disturbance seen in some sampling shafts does indicate that the intrusion of the magmatic material did effect the wall rock to some extent. This zone must be very narrow and has possibly been removed during mining and/or erosion in Bharakan.

No thermal metamorphic effect has so far been noticed. It cannot, however, be said at present that no such metamorphism of the wall rock took place, because very little of the pipe boundary has been exposed. Nevertheless, it would not be surprising if further studies reveal an absence of thermal metamorphism on the walls, because the kimberlite pipes of South Africa also are generally devoid of this effect. It is considered that the temperature of the matter must have been quite low and the magma was possibly blown to pieces by repeated explosions and was cooled due to the large amounts of fragmental material held up within it in suspension due to greater density of the rising mass.

III. THE VOLCANIC PIPE

Surface Plan of the Pipe.—A new map of the area which shows the approximate boundary as deduced from evidence obtained during the present investigation, was prepared. The maximum length of the pipe remains practically the same as noted earlier by the senior author (Mathur, 1953, p. 40), but at its widest, the pipe is now believed to be about 1,000 ft. The shape too remains practically the same, except that the narrow western end appears to swing downwards and the " neck " of the " pear " is narrower.

For marking the pipe boundary, the following evidences were taken into consideration :—

(1) The sandstone outcrop in Bharakan forms a definite limit of the pipe.

(2) The two small outcrops of sandstone on the north-east near the depression of old excavations indicate the probable limit of the pipe there.

(3) The sandstone outcrops at the edges of (i) the pit south of Raja Khadan and (ii) pit No. 2 are almost certainly at the boundary of the pipe as the depths of these pits indicate that they are old workings.

(4) The eastern boundary was established on the basis of old depressions supported by (i) shaft No. 18 in which contorted sandstone was met at a depth of 20 ft. indicating that the boundary was very close, (ii) borehole No. 12 in which the " agglomeratic tuff " was encountered at 50 ft. depth, and (iii) shaft No. 19 in which sandstone was struck at about 27 ft. from the surface.

(5) Borehole No. 10 went only through sandstone, and therefore the boundary was marked just south of it, although the depression of an old excavation extends northwards to the nearby well.

(6) The northern limit of the narrow portion of the pipe was based on the sandstone outcrops and the type of soil obtained in the experimental trenches. A ferruginous gritty material pointed to the possibility of country rock being sandstone, while a grey clayey material indicated the possibility of pipe rock of the type found in sampling shaft No. 11.

(7) Similar criteria were used in marking the southern boundary of the narrow portion of the pipe. The experimental trench brought up some shaly material and, therefore, the pipe was shown to swing southwards towards it. This shale is believed to be similar to the shales found within the pipe in some of the sampling shafts.

(8) Shales were found in sampling shaft No. 21 and they were believed to be similar to the shales found within the pipe area in Bharakan. It was, therefore, included within the pipe area.

Alluvium.—The entire surface of the pipe, except the portions under exploitation, is covered with an alluvial overburden which consists of either (i) original soil, or (ii) refilled gravel and other detrital material. The former is found mostly in the narrow western portion and consists of soil derived in the usual way from the country rock. The refilled material is mainly a variegated clay which has often developed banding and contains a good deal of fine gravel. This gravel is possibly tailings left after washing for diamonds. A number of angular blocks of "agglomeratic tuff" are also found in the refilled material. In a few cases fragments of baskets and cinders were found in clay at depth.

Shales.—Patches of shales are found beneath the alluvial cover in the narrow western portion and on the northern fringe of the pipe. They appear to overlie the tuffaceous material and there is a zone of intermixing between the two. Fingers of shale project into the tuff and *vice versa*. Shale fragments are often caught up within the tuffaceous masses.

The shales in the pipe area appear to be of Jhiri age, because lithologically the two are similar. Both are of the same green and chocolate colours and have the same tendency to break into fine fragments by weathering. They contain very little quartz. The samples of shales found in shaft Nos. 6, 8, 21, etc., were matched with those from the Jhiri shales exposed in the scarp near Majhgawan and from the Shahidan mines, and the similarity of all these was quite pronounced. On the other hand, the shales associated with the Kaimurs are more compact and are somewhat arenaceous. This could be confirmed by microscopic examination of the Palkua shale specimens obtained from the Khamesan gorge and from the bands of shale found intercalated with the Kaimur sandstone in shaft No. 7.

The shale in the pipe area is now found below the surface of the surrounding Kaimur sandstone. It is possible that it was deposited on top of the tuff in the depression of the pipe and is, therefore, found much below the base level of the Jhiri Shales in the nearby outcrops. This is similar to the small outliers of this shale found in the erosional depressions in the Kaimur sandstone surface as at Arsiani near Derara (24°42′ : 80°06′).

An exposure of shales is also seen in the Bharakan pit in contact with the sandstone. It is possibly a remnant of the shale mantle, most of which was removed during mining. The shales found in shaft No. 21 also appear to be of the same nature. Shaft No. 21 is situated very near the boundary of the pipe and the shaft has cut through the top shale layer without reaching the underlying ultramafic rock.

This shale has not been encountered anywhere in the central portion of the pipe area. It is obvious that the deposition of shale took place on an uneven surface and it is possible that the shale from this portion being at quite a high level was eroded away with the shale on the surrounding sandstone area. Another possibility is that the shale was removed from this portion during the extensive mining operations that are going on for the past several centuries.

Age.—The pipe is surrounded on all sides by the Kaimur sandstone into which it is obviously intrusive. It is, therefore, younger than the Kaimur series. Since some shales, which are possibly of Jhiri age, are found within the depression of the neck, they could have only come there after the volcanic activity had subsided. If this is true, it indicates that the pipe is older than the Jhiris. The area around Majhgawan was for a fairly long period a landmass during which the members of the Rewa series lower than the Jhiris were being deposited elsewhere in the Vindhyan basin. It is within this period that the Majhgawan volcanic activity possibly took place. There must have been a fairly long time gap between shales, sufficient for erosion of the extrusive volcanic rock above the vent and formation of a depression there.

IV. THE ULTRAMAFIC PIPE ROCK

"*Agglomeratic Tuff*".—In the shallow quarries excavated within he pipe area, the main diamond-bearing rock is an " agglomeratic uff " of earthy green colour which ranges from a light khaki green to olive green and sometimes has a slight purplish tinge. This green mass is traversed by a network of thin calcite veins which occur in fine sheets having a roughly horizontal attitude, giving the rock a layered appearance. On and near the weathered surface it is quite soft and breaks easily under the fingers, but a freshly quarried rock is quite hard and compact. This, however, also crumbles under the influence of water and other atmospheric agencies. The compact rock has a specific gravity of 2·3 to 2·5.

The green material is almost entirely serpentine and is brecciated, the fragments often enclosed by a " shell " of calcite. The fragments are generally embedded in a finer groundmass of the same mineral. Small veinlets and patches of ferruginous material run through this rock. Sometimes small inclusions, up to three inches across, of various rocks, are found embedded in the groundmass.

The rock forms the main filling in the central and eastern portions of the pipe area which has been excavated for winning the diamonds. It is exposed in Bala Khadan and was found in sampling shafts Nos. 1, 2, 3, 4, 10, 15 and 16.

This same rock was also found in sampling shafts Nos. 12 and 14 but in a weathered condition, and with the notable exception of that in shaft No. 12 and to a lesser degree in shaft No. 14, the calcite veins were very few and practically absent.

In thin section the rock shows numerous grains of serpentine and a few flakes of phlogopite set in a very fine-grained serpentinous groundmass. Plenty of rounded and square grains of ilmenite are present, a large part of which is changed to leucoxene.

The serpentine occurs in grains of yellowish green colour and in some cases of paler shades of green. The grains are mostly rounded to sub-rounded with corroded margins. A good number have the typical hexagonal outline characteristic of olivine.

Both chrysotile and antigorite types of serpentine are present. The chrysotile is mostly fibrous while the antigorite shows aggregate texture. The two minerals occur sometimes independently and in some cases in association with each other.

A few grains of serpentine show some replacement mostly at the margin by a carbonate, probably calcite. Sometimes a whole grain of serpentine has been replaced by a carbonate still retaining the fibrous texture. The replacement has been caused by the carbonate solution filling in the tensional cracks.

A number of grains of some other minerals have also been noted in the serpentinous groundmass. They are mostly ilmenite, hematite, magnetite, perovskite and rutile. Garnet is conspicuous by its absence. The only known presence of this mineral is recorded from shaft No. 8, where a single crystal was picked up from the concentrate.

The groundmass is a very fine-grained, yellowish green, and at place brown ; in this mass are set the pseudomorphs of serpentine, flakes os phlogopite and grains of ilmenite, perovskite, etc. The groundmass af places is practically isotropic under crossed nicols and at places showt the presence of vescicles (?) which are filled with fibrous serpentinous material. It also shows plenty of short and thin yellow fibres and the carbonate grains. The exact composition of the groundmass is difficult to determine. Most probably it is made up of serpentine, a carbonate and a few flakes of phlogopite and plenty of iron-ore.

Calcite Veins in " Agglomeratic Tuff ".—The calcite veins are found only in the upper part of the pipe fillings, as is evidenced by their absence in the " agglomeratic tuff " from sampling shaft No. 12 and from the dark coloured igneous rock found in the boreholes. The depth at which the " agglomeratic tuff " in shaft No. 12 was met with is about 100 ft. below the level of the pipe periphery. The calcite veins disappear at depths lower than this. Those veins were introduced long after the consolidation of the magmatic material in the vent, because in many cases they are found cutting right across the inclusions in this rock. Some calcareous matter is also found in the shales that lie over the tuff (as in shaft No. 6), in the soil found over the tuff (as in shaft No. 11), and in peripheral sandstone (as in shaft No. 18).

A remarkable feature of these veins is that they display a roughly horizontal attitude, giving the " agglomeratic tuff " a layered appearance. Dr. M. S. Krishnan has suggested (personal communication) that the horizontality is probably due to deposition along the varying surface of watertable.

Such calcite ramification of the upper layers is also reported from the kimberlite pipes of South Africa. In some instances the concentration of calcareous matter is so great on the surface that it forms a layer of tufa and travertine, and has led to the discovery of new pipes in South Africa which lay hidden under it. Calcareous tufa is found at several localities around Majhgawan and it would be worth while to make a search for hidden pipes near them.

Weathered Tuffaceous Material.—Some interesting rock types were met with in the narrow western portion of the pipe and on its northern and north-eastern fringe where the ground is virgin and has not been excavated. Under an overburden of 10 to 20 ft. of alluvium occur highly fragmented green and chocolate coloured shales which resemble the Jhiri shale closely. Under 5 to 10 ft. of this shale there occurs a serpentinous tuff with patches, lenticles and veins of calcite. The junction between the shales and tuff is generally sharp though irregular. Sometimes fingers and sheets of one rock intrude into the other. Near the contact there also occur lenses and patches of one rock included in the other. Such shale has been found in shafts Nos. 6 and 8, but in shaft No. 11 the tuff lies directly beneath the soil cover.

The tuff is almost entirely serpentinous. It is soft and friable. At depth, it contains some proportion of the compact agglomeratic material. Although no shaft was sunk deep enough in the tuff, it appears reasonable to suppose that compact agglomeratic tuff and/or the dark coloured igneous variety will be met with under the soft tuff, as is indicated by Sinor's 242 ft. deep borehole (1930, p. 54).

Dark coloured Volcanic Rock.—This rock was brought up by numerous cores in the pipe area and is possibly the main rock of the pipe. It has been found at depths ranging from 90 to 150 ft. from the collar of the pipe. In borehole No. 13 a complete gradation from calcite-bearing yellow-green " agglomeratic tuff " at the surface through dark-green containing very few calcite veins to a calcite-free,and compact,very dark coloured rock can be seen. This makes it clear that the surface " agglomeratic tuff " is only a weathered product of the dark coloured rock. A careful study in hand specimens shows that it is porphyritic with slightly darker grains embedded in the dark matrix. Except for the absence of calcite veins, this rock under the microscope is almost identical with the yellow-green "agglomeratic tuff " of the central portion of the pipe area. The grains of serpentine, however, are more idiomorphic in this rock than in the latter. Good outlines of olivine are recognised and in a few cases some crystals with a little original olivine are also seen. Many crystals show highly birefringent borders of a mineral which from the nature of its occurrence is probably iddingsite, though it is clear and not brown in colour in plane polarised light. Although calcite is not found as veins in this rock, it occurs as minute grains in some of the serpentine and phlogopite crystals. It is probably released from olivine.

Relationship of Various Types.—The composition of all the three varieties is practically the same, although the physical appearance is different. It is clear that the same magma has given rise to these. The dark coloured rock is the original one. The core from borehole No. 13 makes it clear that the yellow-green "agglomeratic tuff " is undoubtedly the weathered portion of the original rock. The soft tuffaceous material has not so far been seen in continuous outcrops with the other two and its exact relationship is not clear.

It is noticed in the field that the soft tuffaceous material is confined to the western narrow portion and to the borders of the pipe on north and north-east. This may appear as if the upper portion of the pipe, at least, has two rock varieties in more or less well defined zones, particularly when it is seen that the incidence of diamonds is different in the two. However, if one remembers that the soft rock is found only in the virgin, unworked portions of the pipe and has never been met with in the previously worked portions, the conclusion that the former if present has been removed during excavations becomes quite obvious.

The yellow-green rock found in the central portion of the pipe area was given the name " agglomeratic tuff " by Sinor (1930), which has remained in vogue so far. It passes at depth into a compact dark coloured rock which does not show the agglomeratic or brecciated character although the two have the same composition. The brecciation is simulated by the following factors : (1) The original rock is porphyritic (although the phenocrysts cannot be easily seen, being almost as dark as the groundmass), and owing to differential weathering of the rock in the upper portion, they remained dark while the groundmass became lighter in colour. (2) The fragmentation is largely caused by calcite veins, which were introduced much later and are due to the same agent, namely groundwater, that caused the weathering. (3) Where inclusions are present they add to the agglomeratic appearance. (4) Of course, there has also been some brecciation of the original magmatic material, especially near the mouth of the vent.

Chemical Composition.—Two samples of the "agglomeratic tuff" one each from sampling shaft Nos. 2 and 15, were chemically analysed, Their compositions are given in columns 1 and 2 of Table 1, in which the analyses of the Majhgawan "agglomeratic tuff" quoted by Sinor (1930) and some selected analyses of kimberlites of South Africa are also given for comparison. A look at this table shows that there is a general resemblance between the composition of the Majhgawan rock and those of the kimberlites.

However, there is a significant difference between the chemical composition of the samples from shaft Nos. 2 and 15 and those of Sinor. In the former lime is in greater amount than in the latter. This appears due to greater proportion of calcite veins in the former samples (which were obtained from nearer the surface), than in the samples collected by Sinor (which were obtained from a borehole at a depth of over 100 ft., presumably from the fresher dark coloured ultramafic rock which contains very little calcite).

The various analyses of the Majhgawan rock are superficially similar to those of the kimberlites and melilite-basalt from South Africa. Two noteworthy features of the former are the low magnesia and higher titanium oxide than in the kimberlites. The amount of magnesia is just a little less than in melilite-basalt, while it is very much less than in the two types of kimberlites. Titanium oxide is much higher than in either kimberlites or melilite-basalt. The different analyses are given in the following Table No. 1.

TABLE II.

	Majhgawan Shaft No. 2	Majhgawan Shaft No. 15	Core from Sinor's Borehole from Majhgawan			Basaltic kimberlite	Micaceous kimberlite	Melilite-Basalt.
	1	2	3	4	5	6	7	8
SiO_2	30·30	25·06	38·16	36·96	37·36	30·95	31·80	31·17
Al_2O_3	2·54	4·72	4·89	6·25	4·49	4·17	3·41	6·25
Fe_2O_3	6.80	7·18	5·80	6·00	3·48	6·16	5·19	3·22
FeO	0·62	0·56	5·58	5·40	5·11	2·66	3·48	9·64
Cr_2O_3	0·29	0·28	0·05	0·05	0·11	—	—	—
TiO_2	4·16	3·80	6·85	6·85	5·70	2·34	1·40	2·91
MnO	0·08	0·11	0·30	0·30	0·17	trace	—	—
NiO	0·14	0·13	0·16	0·29	—	—	—	—
CaO	15·03	18·80	6·72	6·72	7·24	8·92	10·04	17·76
NgO	15·39	14·00	15·40	14·76	16·47	32·30	24·69	19·90
Na_2O	0·46	0·31	nil	nil	0·62	0·35	0·29	2·03
K_2O	0·27	0·15	nil	nil	0·50	1·61	4·32	2·51
P_2O_5	0·58	0·53	0·51	0·75	0·89	—	1·49	1·69
CO_2	8·20	10·60	5·52	6·88	6·03	2·54	7·65	—
H_2O+	5·76	5·88	4·60	3·60	4·48	6·81	5·59	2·05
H_2O-	8·64	8·47	5·42	5·66	6·06	0·55	0·63	0·44
SO_3	0·10	Trace	Trace	Trace	0·14	—	—	—
TOTAL	99·36	100·58	99·96	100·47	99·85	99·36	99·98	99·62

1 and 2 : Analyses by Geological Survey of India.
3 and 4 : Analyses by J. Parry, De Beers consolidated Mines Ltd., Sinor (1930, p. 147).
5 : Analysis by Imperial Institute, London, Sinor (1930, pp. 149-150).
6, 7 and 8: Analyses quoted in Wagner (1914, pp. 81 and 110).

Nomenclature.—The Majhgawan rock found in the centre of the pipe area has been referred to as an " agglomeratic tuff", a term originally proposed by Sinor (1930). This is only a rough description and conveys no idea of its mineralogical composition. Moreover, the recent work that has shown that it is nothing more than the weathered product of a volcanic rock and that the agglomeratic appearance is only superficial, makes this term unsuitable. The only true tuff is possibly the soft rock of the narrow western portion of the pipe. It appears necessary to drop this term, but it has been used in this report, for want of a better one, within inverted commas.

The Majhgawan rock is composed almost entirely of serpentine with minor quantities of some accessory minerals like phlogopite, ilmenite, etc., and is different from the typical kimberlite which has a more complex assemblage of minerals. In this connection we may recall the significant remarks of du Toit that " ....I consider that the petrological and chemical differences are sufficiently pronounced to prevent us from classifying the Indian material among the kimberlite proper" (Sinor, 1930, p. 146).

A comparative study with the thin sections of South African kimberlite shows that the Majhgawan rock, although mineralogically not identical, bears general resemblance to it in so far as the texture and the arrangement and occurrence of serpentine go. Since it is also diamond-bearing, the Majhgawan rock is probably related to kimberlite.

V. INCLUSIONS

The inclusions found within the pipe are of two types, namely, (i) cognate and (ii) accidental. Cognate inclusions are concretions or segregations that have formed in the magma of the pipe rock during or just prior to its solidification, but they are always sharply defined from the enclosing rock. Accidental inclusions are masses or fragments of rock torn away from the formations through which the pipe has passed.

Cognate Xenoliths.—Small inclusions of a dark coloured rock are scattered throughout the " agglomeratic tuff ". Although one or two were seen in almost every sampling shaft, they were obtained in abundance from shaft No. 16. They generally have rounded outlines indicating that they were subjected to attrition by the rising magma. Some have sharp boundaries and can be dislodged easily from the enclosing rock, while others are so intimate that they cannot be separated though they have well defined outlines. In some cases the calcite veins cut right across the latter type of inclusions.

A dark green xenolith which was frequently obtained from shaft No. 16 is a very fine-grained highly altered rock which may have been originally a pyroxenite. At present it consists mostly of hornblende, chlorite and ilmenite with a little magnetite. Its texture is like that of an igneous rock.

Another type of cognate xenolith consists of abundant lath-shaped flakes of green biotite set in a very fine-grained fibrous sepentine groundmass charged with a considerable quantity of hematite. This type of inclusion is more common. Sometimes the iron-rich portion forms a red zone around green serpentinous mass, while in other cases the former forms the nucleus within the green sepentine. The groundmass of such inclusions is very similar to the host rock, namely the " agglomeratic tuff ".

An interesting pebble-like inclusion of hematite was found in the " agglomeratic tuff " of Balakhadan. It is a flat, rounded pebble and shows concentric layers of iron-ore, with serpentinous material occurring as fine partings between hematite layers and in the core (Plate 2, Fig. 2).

Accidental Inclusions.—Inclusions of shales, hematite, jasper, chert and vein quartz are often met with in the " agglomeratic tuff ". They are generally well rounded and may have been derived mainly from the Kaimur conglomerate which is rich in pebbles of all the above, except the shales. Of course, there is the possibility that some inclusions may have come from the Semri and Bijawar beds underlying the Kaimurs, and got rounded by attrition in the rising magma. So far, no inclusions of the basement Bundelkhand granite have been observed. The size of these inclusions is generally one inch or less, and the largest seen are four inches across.

The shales found in the upper parts of the shafts in the narrow western portion and near the boundary elsewhere in the pipe have been discussed in an earlier chapter. They are generally confined to the weathered " agglomeratic tuff ", and are not true inclusions, as the mode of their occurrence is believed to be unlike those of other inclusions. The shale " inclusions " are always of quite large size, and are generally angular.

Some shales, however, are found in the matrix of the compact " agglomeratic tuff " and appear to have been derived from the Semri and Bijawar formations. These are usually dark in colour and are found in well rounded pebbles, up to about one inch across in size.

PART III—SAMPLING

VI. GENERAL REMARKS ON SAMPLING

Shafting Procedure.—Old records and some boreholes sunk during the past few years by the Syndicate showed that a large part of the pipe area was filled with waste from the old workings. In some portions of the pipe the waste was expected to be as much as 80 ft. deep from the level of the surrounding country rock. It was believed that about 40 ft. would be the average depth of a sampling shaft and the scheme of work was drawn up accordingly. The Russians desired that the entire sampling should be completed in 25 days. The work of sinking of the shafts was entrusted to the Indian Bureau of Mines and the Deputy Mining Engineer of the Department was in-charge of the operations. Owing, however, to the delay in obtaining the necessary equipment, difficulties in securing labour and local supplies like timber, steel, etc., the work was carried out very much behind schedule. During a period of eight and a half months, only about 704 ft. of shafts could be sunk, leaving much of the work unfinished.

Sampling Procedure.—The material obtained from each shaft was divided into two portions. The first consisted of the alluvial overburden often containing broken pieces of the " agglomeratic tuff ". The second consisted of the " agglomeratic tuff " or in some cases of disintegrated tuff with shale, etc. The overburden samples were also intended to be treated for diamonds in sections of 40 tons each (that is, about 16 feet column) in each shaft. Since this material was quite damp it was spread out for drying under instructions of the Russians. However, the sudden rains scattered some of these samples and later, as the work progressed, the alluvial overburden samples were not treated further. Of the two samples treated in the early stages, one completely and another partially, only the former yielded some diamonds. The " agglomeratic tuff " pieces found in the alluvium were not treated, though in the beginning it was proposed to crush and wash them for diamonds.

A 40-ton sample of " agglomeratic tuff " was taken from each shaft. In those shafts where this rock could not be obtained within convenient depths, the shale-mixed disintegrated tuffaceous material was taken as the sample and milled for diamonds. In all these cases exact quantities of 40 tons could not be taken and the weight varied up to 100 tons.

Depending upon the specific gravity, it was calculated that in a shaft, 8 ft. × 6 ft., it will be necessary to dig to the following depths to obtain 40 tons of the various materials :

	Ft.
1. Alluvial overburden	16·4
2. Disintegrated tuff	13·3
3. Compact Agglomeratic tuff	12·5

Treatment and Milling.—Since damp alluvial overburden samples could not be run through the mill, it was decided at the instance of the Russians to wash them manually in pits locally called 'donas'. A row of such pits was constructed near shafts 4, 13 and 16 in addition to renovating an old 'dona' near the rectangular well for the purpose. Only about 35 tons of material from two shafts was treated manually.

The main pipe rock samples were treated in the recovery mill of the Syndicate. The hard and compact "agglomeratic tuff" was crushed, while softer material was screened through trommels before being concentrated. The material was passed over grease tables, but as a final check it was hand sorted by trained women workers.

The diamonds obtained were sealed under the signatures of an officer of the Indian Bureau of Mines, a representative of the Syndicate and the Diamond Inspector, and deposited with the Diamond Officer who kept an accurate record of the weights and physical descriptions.

Security.—The Vindhya Pradesh Government deputed a posse of policemen in addition to sepoys of the Diamond Office. They were present at the work sites and the mill ; the policemen were also on duty during the night at the hand sorting platform. The number of the guards, however, was so small that they could not possibly do any actual checking except for exercising a psychological influence over the workers. An officer or technical assistant of the Government sampling party was also always present at all important sites of work. In spite of all these arrangements the possibilities of theft and salting at the place could not be ruled out altogether.

Progress of Sampling.—At the close of the operations the following was the final progress recorded in sinking of shafts :

1. Shafts completed—14 (Nos. 1, 2, 3, 4, 5, 6, 8, 10, 11, 12, 13, 14, 15 and 16).
2. Shafts in sandstone and shale abandoned—5 (Nos. 7, 9, 18, 19 and 21).
3. Shaft abandoned owing to collapse—1 (No. 20).
4. Shaft not started at all—1 (No. 17).

The position regarding actual beneficiation of samples was as follows :—

1. Alluvial overburden samples treated—1 full (No. 3) and 1 partial (No. 6.)
2. 40-ton agglomeratic tuff samples milled—9 (Nos. 1, 2, 3, 4, 10, 12, 14, 15 and 16).[1]
3. Shaly and tuffaceous samples milled—5 (Nos. 5, 6, 8, 11 and 13).
4. Ferruginous sandstone milled—1 (No. 7).
5. Sandstone and shale milled—1 (No. 18).

---

[1] In addition to these a 40-ton sample of "agglomeratic tuff" from Balakhadan was also milled at the instance of the Russian specialists as an experiment. has not been included in the calculation of the grade as it was not obtained from regular sampling shaft.

The final sinking data of the sampling shafts are given in Table 2.

TABLE 2.

Sinking Data of the Sampling Shafts.

Shaft No.	Depth from Ft. In.	Depth to Ft. In.	Total Ft. In.	Description of rock
1	00 00	22 02	22 02	Alluvium containing a few "agglomeratic tuff" pieces.
	22 02	34 08	12 06	Hard "agglomeratic tuff".
2	00 00	11 06	11 06	Alluvium containing a few "agglomeratic tuff" pieces.
	11 06	24 00	12 06	Hard "agglomeratic tuff".
3	00 00	10 00	10 00	Alluvium containing a few "agglomeratic tuff" pieces.
	10 00	22 06	12 06	Hard "agglomeratic tuff".
4	00 00	23 06	23 06	Alluvium containing a few "agglomeratic tuff" pieces.
	23 06	28 06	05 00	Alluvium mixed with altered tuff.
	28 06	41 00	12 06	Hard "agglomeratic tuff".
5	00 00	20 05	20 05	Alluvium.
	20 05	46 08	26 03	Dark tuffaceous clay with shale.
6	00 00	09 03	09 03	Alluvium.
	09 03	43 07	34 07	Soft tuff mixed with shale.
7	00 00	06 00	06 00	Alluvium.
	06 00	18 00	12 00	Ferruginous sandstone.
	18 00	25 00	07 00	Sandstone with micaceous sandy shale.
8	00 00	15 00	15 00	Alluvium.
	15 00	41 02	26 02	Soft tuff with shale.
9	00 00	06 00	06 00	Alluvium.
	06 00	08 00	02 00	Sandstone.
10	00 00	13 06	13 06	Alluvium with abundant tuff pieces.
	13 06	26 00	12 06	Hard "agglomeratic tuff".
11	00 00	07 00	07 00	Alluvium.
	07 00	33 06	26 06	Soft tuff with clayey and shaly matter.

TABLE 2—*contd*.

Shaft No.	Depth from Ft. In.	Depth to Ft. In.	Total Ft. In.	Description of rock.
12	00 00	32 10	32 10	Alluvium.
	32 10	46 06	13 08	Friable and soft "agglomeratic tuff".
13	00 00	48 00	48 00	Alluvium.
	48 00	61 06	13 06	Shale and tuffaceous material.
14	00 00	38 00	38 00	Alluvium.
	38 00	52 00	14 00	Soft "agglomeratic tuff".
15	00 00	18 06	18 06	Alluvium containing a few pieces of "agglomeratic tuff".
	18 06	31 00	12 06	Hard "agglomeratic tuff".
16	00 00	13 06	14 06	Alluvium.
	13 06	26 00	12 06	Hard "agglomeratic tuff" containing numerous inclusions of ferruginous nodules and diabase.
17		NOT	SUNK.	
18	00 00	31 00	31 00	Alluvium.
	31 00	40 05	09 05	Hard sandstone and shale.
19	00 00	27 00	27 00	Alluvium.
	27 00	29 00	02 00	Micaceous sandstone and shale.
20	00 00	43 04	43 04	Alluvium.
21	00 00	25 00	25 00	Alluvium with some shale and tuff pieces.
	25 00	30 06	05 06	Hard laminated shale with intercalation of sandstone.

VII. SAMPLING RESULTS

Out of the projected total of 21 samples of the pipe rock, only 14 could be obtained. Out of these only nine were of "agglomeratic tuff" and the remaining of weathered and disintegrated tuff containing some shale. The results of agglomeratic tuff samples only were taken into account for calculating the average grade of the pipe rock because of the following reasons :

1. It is the pipe rock from which the diamonds were hitherto obtained and which was the target of the sampling. The weathered rock, on the other hand, is so much mixed with shale that it would have caused confusion in the calculation of the average grade. For sampling, only one lithological type was taken to avoid confusion,

2. Accurate 40-ton samples only of the "agglomeratic tuff" were obtained. The weights of the remaining samples varied greatly. To reduce the weight and value proportionately of the diamonds obtained from these samples to conform to 40-ton weight, would have been inadvisable, as it would have introduced more uncertainty in the results since the diamonds are sporadically and irregularly distributed in the rock.

The average diamond content has been calculated for 100 loads and not tons, because a 'load' is the internationally accepted standard measure of diamond bearing pipe rock or kimberlite. A load is equivalent to 0.8 ton. Similarly the *ratti*—the measure in which the diamonds are weighed in Panna—has been replaced by metric carat, the international measure of gem weight. The original record in the Diamond Office is kept in *rattis*, but for the purpose of calculations the *rattis* have been converted into metric carats in this report. The *ratti* is equivalent to 0.985 metric carat. The consolidated production given in Tables 3 to 7 has been shown in carats only. In the detailed description of diamond production given in Appendix E (Tables 22 to 40) the weight, however, has been shown in *rattis*, because they are true copies of the original record maintained by the sampling party and the Diamond Office.

"*Agglomeratic Tuff*" *Samples*.—Table 3 below gives the production of diamonds from the nine "agglomeratic tuff" samples obtained during the sampling operations. The results show that the average diamond content is about 9.41 carats valued at approximately Rs. 1,400 per 100 loads (or 11.76 carats valued at Rs. 1,750 per 100 tons). These samples were obtained from shafts located in the central portion which has been exploited in the past. The area of influence formed by the sampling shafts is shown in Plate 8.

TABLE 3.

Production from samples of "agglomeratic tuff"

Shaft No.	Weight of sample	Number of diamonds	Weight of diamonds	Approx. value
	Tons		Carats	Rs.
1	40	12	4·82	340·00
2	40	3	2·39	308·00
3	40	6	8·19	2,994·00
4	40	Nil	Nil	Nil
10	40	4	5·00	373·00
12	40	10	5·22	361·00
14	40	5	4·31	779·00
15	40	4	1· 1	189·00
16	40	19	11·09	950·00
TOTAL .	360	63	42·33	6,294·00

In order to obtain a complete picture of the average grade of the pipe rock it is essential to find out the proportion of industrial diamonds to gem quality stones. The production shown in Table 3 has been split into the two qualities of diamonds and the number, weight and approximate value of each is shown separately shaftwise in Table 4 given below.

TABLE 4.

Production of Industrial and Gem quality diamonds from "agglomeratic tuff" samples.

Shaft No.	Gem Diamonds			Industrial Diamonds		
	No.	Weight	Approx. value	No.	Weight	Approx. value
		Carats	Rs.		Carats	Rs.
1	3	1·88	211·00	9	2·94	129·00
2	3	2·39	308·00	Nil	Nil	Nil
3	1	3·58	2,756·00	5	4·61	238·00
4	Nil	Nil	Nil	Nil	Nil	Nil
10	2	1·53	230·00	2	3·47	143·00
12	5	2·96	266·00	5	2·27	95·00
14	5	4·31	779·00	Nil	Nil	Nil
15	3	0·85	169·00	1	0·46	20·00
16	8	5·97	724·00	11	5·12	226·00
TOTAL.	30	23·47	5,443·00	33	18·87	851·00

From the foregoing it can be seen that the average for the two qualities is as follows :

Gem quality : 5·21 carats per 100 loads valued at approx. Rs. 1,210·00.
Industrial : 4·19 carats per 100 loads valued at approx. Rs. 190·00.

The proportion of cuttable gems and industrials is roughly 5 : 4 by weight.

A reference to the foregoing Table will show that one gem diamond weighing 3·58 carats and valued at approximately Rs. 2,756 has served to enhance the average value.

Another important point to be borne in mind while considering the average, is the average weight of each diamond, because unlike other commodities the value of diamonds does not increase by a simple rule of three. For example, a four carat stone will not be valued at four times the price of a one carat diamond of the same quality, but will fetch a price much more than four times the price of the latter. In Table 5 the average weight of a single industrial and a single gem quality diamond is given shaftwise. The average for the total of "agglomeratic tuff" samples is also given at the bottom.

TABLE 5.

Average weight of one diamond from "agglomeratic tuff" samples.

Shaft No.	Gem quality	Industrial	Combined total
	Carats	Carats	Carats
1	0·62	0·33	0·40
2	0·80	Nil	0·80
3	3·58	0·92	1·37
4	Nil	Nil	Nil
10	0·77	1·73	1·22
12	0·59	0·45	0·52
14	0·86	Nil	0·86
15	0·28	0·46	0·33
16	0·75	0·47	0·58
Average of whole area.	0·78	0·57	0·67

Tuffaceous and Shaly Samples.—These samples have been discussed separately from those of "agglomeratic tuff" for reasons already stated. It was originally intended to take the shafts right through them until the massive "agglomeratic tuff" was reached. But the overburden of tuffaceous and shaly material proved too much, and whatever material could be obtained from these shafts was treated as sample and milled for diamonds. It is difficult to describe the exact lithology of each sample because the rocks are often largely weathered and intimately intermixed.

Generally there is a soft tuffaceous material which appears to be a weathered and disintegrated product of the "agglomeratic tuff" and it contains a varying amount of shale. In one case the serpentinous matter was quite little while clay and shale proportion was very high. Table 6 gives the production from these samples.

TABLE 6.

Production from samples of shaly and tuffaceous materials.

Shaft No.	Lithology of sample	Weight of sample	No. of diamonds	Weight of diamonds	Approx. value
		Tons		Carats	Rs.
5	Tuffaceous clay . .	75	1	0·05	2·50
6	Shale and disintegrated tuff.	98	2	1·25	56·50
8	Shale and disintegrated tuff.	75	1	0·51	17·00
11	Highly weathered tuff with clay and a little shale.	75	Nil	Nil	Nil
13	Dark clay shale with tuffaceous matter.	40	Nil	Nil	Nil
	TOTAL .	363	4	1·81	76·00

It would not be strictly accurate to calculate the average diamond content of the shaly and tuffaceous material, because the lithology and weight of the samples are variable in each case. However, if an average is taken it works out at 0·40 carat valued at approximately Rs·17·00 per 100 loads (or 0.50 carat valued at Rs· 21.00 per 100 tons).

Alluvial Overburden Samples.—The alluvial overburden is of two types ; one is the top soil and the other waste which refills the ancient workings. In the central portion from where the "agglomeratic tuff" samples are obtained, it is clear that the overburden consists of refilled waste, because it contains a large number of blocks of "agglomeratic tuff", washed gravel and even bits of pottery and wicker-work. It is quite likely that this waste also contains a few stray diamonds, which escaped the notice of ancient workers. Some of the embedded "agglomeratic tuff" pieces may also contain diamonds. The original soil occurs on the western portion of the pipe area and possibly on its fringe in other parts. This soil is also likely to contain diamonds, because the disintegration of the pipe rock upon weathering may yield a few stones.

The overburden samples were kept carefully in the beginning after separating the "agglomeratic tuff" blocks. It was planned to treat these two separately and add up the results in the final analysis. One soil sample was manually washed, but the tuff blocks embedded in it could not be treated for diamond. Another alluvial sample was started but abandoned after only a very small portion was washed.

In Table 7 the results of the beneficiation of these alluvial samples are given. Although it would be meaningless to compile averages from practically a single sample, it is instructive to find that if the average diamond content is calculated, it works out at about 2.61 carats, valued at approximately Rs. 265.00 per 100 loads of alluvial overburden.

TABLE 7.

Production from samples of alluvial overburden.

Shaft No.	Weight of sample	No. of diamonds	Weight of diamonds	Approx. value
	Tons		Carats	Rs.
3	30	4	1·14	116·00
6	5	Nil	Nil	Nil
TOTAL .	35	4	1·14	116·00

Sample. from Balakhadan.—Only two regular samples from shaft Nos. 2 and 3 could be treated in the presence of the Russian specialists. Since the results from these were inadequate for forming any idea about the value of the deposits, they suggested that a 40-ton sample of the "agglomeratic tuff" be quickly obtained from Balakhadan quarry and treated in the mill. This was done, and 10 diamonds weighing 9.89 carats valued at approximately Rs. 563·00 were obtained.

It must be clearly understood that this sample was obtained only as a measure of control, and is not to be taken into account while calculating the results of the "agglomeratic tuff" samples obtained from the regular sampling shafts. The details of the diamonds obtained from this sample are given in Table 25.

Recovery Mill.— The mill can be divided into three sections. The first one handles hard and compact materials that require crushing. The second section takes gravel and other mterials not requiring crushing. The third section consists only of control washing pans and can be connected with either or both of the first two sections.

In the first section, "agglomeratic tuff" or conglomerate is first crushed, concentrated in the washing pans, passed through a vibrating screen, and finally sent over a grease table to hand-sorting platform.

The second section consists of trommels, washing pans, a Denver Jig and a grease table, with final hand sorting.

The washing pans and a grease table only form the third section, which is used for checking the fine portion coming as overflow from the washing pans in the first two sections.

PART IV— CONCLUSIONS AND RECOMMENDATIONS

VIII. CONCLUSIONS ON SAMPLING

The production of diamonds from the sampling shafts in the "agglomeratic tuff" comes to about 9·41 carats per 100 loads (or 11·76 carats per 100 tons). Each sample weighed only 40 tons, and the total weight of the rocks treated was 360 tons, which is not adequate for sampling a deposit of this kind in which the diamond is so sparsely and erratically distributed. However, since this is the only reliable sampling data available, it may form the initial basis for all future considerations and plans.

It would have been best if one could rely on the actual exploitation data of the Majhgawan mine. A record of some kind is kept by the Syndicate, *but the authors have strong doubts about its reliability* ; because from personal observations it is found that there is no system of weighing or measuring the ore treated and very rough estimates are made while posting the register. The Table 8 below gives the production figures from Majhgawan as communicated by the Syndicate to the Russian specialists.

TABLE 8.

Ore and diamond output from Majhgawan from 1953-1955 (Data supplied by the P. D. M. Syndicate. Ltd.)

Year	Ore treated	Number of diamonds obtained	Weight		
			Rattis		
	Tons		Ra.	An.	Carats
1953	1,750	124	102	7	93·22
1954	3,400	176	170	6	155·05
1955	900	67	54	12	49·43
TOTAL	6,050	367	327	9	297·70

On the basis of this data, the actual diamond production from Majhgawan works out at only about 3·94 carats per 100 loads or about 4·92 carats per 100 tons. This is less than half the value arrived at by consideration of the present sampling results.

For the sake of comparison the average diamond contents of some of the South African kimberlite pipes are given below (Anon, 1956, p. 272) :

Kimberley mine. . . .	74 Carats/100 loads.
Roberts Victor Mine . . .	32 Carats/100 loads.
Jagersfontein Mine . . .	6 Carats/100 loads.
Dutoitspan Mine . . .	11 Carats/100 loads.
Wesselton Mine. . . .	25 Carats/100 loads.

Quality of Diamonds.—Of the diamonds obtained during the sampling (both from the fresh " agglomeratic tuff" and disintegrated tuffaceous material), 52 per cent. by weight were gem quality, while the remaining were industrial bort. The actual production data compiled by the Diamond Officer show that the ratio between the two qualities varied from year to year. It is given in Table 9.

TABLE 9.

Production of Diamonds from Majhgawan mine, 1952-55.

(According to Quality : Approx. weight in carats).

Year	Total	Gem quality	Industrial	ratio (rough) gem to industrial
1952 . .	176	60	116	1 : 2
1953 . .	93	22	71	1 : 3
1954 . .	155	83	72	1 : 1
1955 . .	49	16	33	1 : 2
TOTAL .	473	181	292	2 : 3 (Average)
Sampling .	42	23	19	1 : 1

It can be seen that, on the whole, more industrial diamonds are produced than gem quality ones, the average ratio being 3 : 2.

Distribution of Diamonds.—Most of the diamonds during sampling were found in the "agglomeratic tuff". A few were obtained from the disintegrated tuff also. It is, therefore, to be noted that the latter is also to be treated for diamonds and should not be discarded.

The Russians had suggested that the alluvial overburden from each shaft should also be washed for diamonds. Owing to several factors only one such sample could be treated and a few small diamonds were recovered. This has clearly shown that the alluvium is also diamond-bearing and should not be discarded. The gems were possibly introduced in the alluvium from (i) "agglomeratic tuff" pieces caught up in refilled soil, (ii) an original diamantiferous gravel layer and/or (iii) tailings which could not be completely treated by the ancients. The alluvium need not be treated separately, but it can be mixed with the pipe rock in place of clay which is used for giving the required density to the pulp in the washing pan.

Reserves of Diamonds.—Most of the gems have come from the central portion of the pipe area in which compact "agglomeratic tuff" is exposed. As far as the present state of our knowledge and experience goes, only this rock deserves full attention, and the mining activity in the first stages can profitably be confined to this portion.

This rock, however, is expected to be found to a depth of about 100 ft. only from the rim of the pipe. Beyond this depth it passes into a rock of entirely different physical appearance. The latter has been brought up in small cores by drilling, and has not been studied for its diamond content. The record of the boreholes shows that it possibly forms the main pipe filling and that the yellow coloured "agglomeratic tuff" sampled and exploited so far forms only the top layer, which is a very small part of the whole pipe. Since we do not yet know whether this dark coloured ultramafic rock is diamantiferous, the results of the present sampling may hold good only up to the depth of 100 ft. from the top. Since about 40 ft. of the upper layer has been removed in earlier mining activity, and the area of influence of the sampling is in the central portion of the pipe only, which is about 562,500 sq. ft. in area, it follows that the following amount of ore may be available :

562,500 × 60 = 33,750,000 cu. ft.
= 2,250,000 tons.
= 28,125 hundred loads.

Sampling has shown that the diamond content is about 9·41 carats per hundred loads. Assuming that this incidence of diamond is probable in the entire 60-foot top layer, the following diamond reserves may be inferred :—

28,125 × 9·41 = 264,656 carats, or, say, 250,000 carats of diamonds.

This estimate is to be taken with caution and is merely hypothetical. Further bulk sampling will be needed to assess the real value of the deposit.

IX. RECOMMENDATIONS.

The present study and sampling of the Majhgawan diamond deposit has shown that it is one of the most interesting formations, both from the commercial and scientific points of view. It is, therefore, strongly recommended that very thorough investigations of this and other similar deposits should be made. The recommendations given here have been drawn up to indicate the possible work which should be undertaken in the first stages. They are not comprehensive, but would serve as the basis for detailed work.

Geological and Geophysical[1] *work at Majhgawan.*—This deposit is a unique one. The studies made so far, admittedly from the little material available, show that petrologically it is unlike the kimberlites of South Africa. A scientific study of Majhgawan would be most instructive. It is suggested that the following steps be taken to study the Majhgawan:—

1. A series of boreholes should be sunk in the pipe area at intervals of 250 feet. They should be located in the centres of the squares formed by the grid lines of the present sampling scheme. Each hole should at least be 200 ft. deep. Three holes, two in the central and one in the western neck of the pipe area, should be taken at least to a depth of 500 feet. The cores will give valuable informtion about the variation in the morphology of the pipe rock both laterally and vertically. They should be logged by an experienced geologist.

2. Careful petrographic, chemical and physical studies of the cores should be made. Some portions should be crushed and treated for heavy minerals, including diamonds.

3. The shape of the pipe and its variation at depth will be of great use in making a calculation of reserves. The best way in which it can be done is to carry out a geophysical survey.[1] Particular attention should be paid to find out whether there is a significant change in the rock of the pipe itself and whether there are any fissures or dykes of the ultramafic rock near the main pipe. In South Africa some dykes of this type are diamond-bearing.

Since in Africa kimberlite pipes generally occur in clusters, it may reasonably be assumed that similar may be the case in Bundelkhand. If there are any pipes near Majhgawan, they have not come to light so far and may be hidden under alluvium and/or younger formation. If the age of the Majhgawan pipe is pre-Jhiris (or post Kaimur) some of the shale may be hiding these pipes. A geophysical survey in this area may, therefore, reveal something of interest.

In South Africa it has been noticed that the concentration of calcite in the surface portion of the volcanic vent becomes so great that deposits of calcareous tufa are formed on the top, and form a useful indication of the presence of a kimberlite pipe underneath. It is, therefore, suggested that special studies of the calc-tufa deposits in this area should be made.

Geological and Geophysical Work in Other Areas.—Pipe rock similar to that of Majhgawan has been found at Angor in the neighbouring Chhatarpur district (Jhingran and Puri, 1956). Since only a small exposure has so far been seen, it would be worth while to study the nature of this deposit. It is, therefore, recommended that a geophysical investigation of this should also be made. Afterwards it should be studied by trenching and pitting, and milling of the rock for diamond content.

---

[1] Magnetic and resistivity surveys of a part of the Panna diamond field have since been carried out by the Geological Survey of India between 1956 and 1959. Their results will be published separately.

Although the samples obtained from Angor closely resemble the yellow-green " agglomeratic tuff" of Majhgawan, it is yet to be proved whether they are diamond-bearing. Several kimberlite pipes in Africa have been found barren of diamonds.

Sampling Work.—It has been pointed out that the amount of ore treated during the present sampling operations was not adequate. It would be desirable if run-off-mill tests are made. This can be done only under the supervision of a Government officer who should ensure that the ore fed into the mill is carefully weighed or measured, and correct records maintained. There is no trouble regarding the weight of the diamonds, as it is carefully recorded by the Diamond Office. It must, however, be seen that each batch of ore and diamonds obtained therefrom are correlated.

It has also been mentioned earlier that all diamonds so far have come from the surface "agglomeratic tuff" and the diamantiferous nature of the dark ultramafic rock occurring beneath it has yet to be ascertained. It is strongly recommended that an exploratory shaft should be sunk in the middle of Balakhadan (being the lowest point yet reached in the pipe area), and the unweathered dark rock taken out for sampling. It would be better if not less than 100 tons of this ore are treated.

Since the microscopic examination reveals that both the types of rock are similar in composition and that possibly the yellow "agglomeratic tuff" is only a weathered product of the dark coloured rock, it is believed that the latter too is diamond-bearing. However, this deduction should be confirmed by actual tests.

Mining and Milling.—The present mining and milling at Majhgawan are highly unsatisfactory. There is no planning either in mining or in milling. For the proper development and utilisation of this property, it is absolutely essential to adopt practical and sound mining and milling techniques. In the early stages the pipe should be developed as an opencast. Later, mining by the "block-caving" method may be practiced. It has proved highly successful in South African pipe occurrences.

APPENDICES

APPENDIX A

Drilling Results

At Majhgawan the authors found, lying in an obscure corner, some cores of a rock obtained from within the pipe that was entirely different in appearance from any seen on the surface of the deposit. It was very dark in colour and did not show any calcite. Enquiries revealed that these cores were obtained by drilling in the pipe area a year or two back by the Syndicate. Unfortunately, the cores were all mixed up and their logs were not well kept. However, they served to indicate that the nature of the rock in the pipe changed with depth and pointed to the desirability and importance of drilling.

A Calyx drill was lying at the mine, but it was not in good working order. After a great deal of effort, it was repaired and put into operation on the 30th May, 1956. Since only one hole could be drilled during the short time at our disposal, the deepest point in the pipe area, namely, the bottom of the Balakhadan quarry, was selected in order to reach the maximum relative depth possible. The following Table 10 gives the log of this hole. This hole actually reached a depth of 62 ft. up to the end of July, 1956, but the last 13 ft. of core could not be taken out owing to the jamming of the core barrel. There were frequent stoppages owing mainly to break-down in the machinery and labour shortage.

TABLE 10.

Section of borehole No. 13 at bottom of Balakhadan

(R.L. 43.34)

Description of rock	Thickness		Depth from surface	
	Ft.	In.	Ft.	In.
Light green "agglomeratic tuff" with almost horizontal calcite stringers.	9	5	9	5
Dark green band	0	1	9	6
Olive green "agglomeratic tuff" with horizontal calcite stringers.	2	12	12	6
Light green "agglomeratic tuff" with horizontal calcite stringers.	1	0	13	5
Dark green "agglomeratic tuff" with horizontal calcite stringers and bands of ferruginous matter.	1	11	15	4
Light green "agglomeratic tuff" having dark patches with horizontal calcite veins.	0	6	15	0
Dark green "agglomeratic tuff" with roughly horizontal calcite veins having numerous dark inclusions.	2	5	18	3
Dark green "agglomeratic tuff" with irregular calcite veins.	1	9	20	0
Dark green "agglomeratic tuff" with a few fine irregular calcite stringers becoming fewer with depth.	7	0	27	0

A PPENDIX A—contd.

TABLE 10—*contd.*

Description of rock	Thickness		Depth from surface	
	Ft.	In.	Ft.	In.
Very deep green "agglomeratic tuff" with irregular but prominent calcite stringers.	2	4	29	4
Dark green slightly porphyritic igneous rock without calcite stringers.	2	0	31	4
Dark green rock with a few calcite stringers :	0	3	31	7
Very dark green (almost black) igneous rock without any calcite (slightly porphyritic).	10	4	41	11
Grey sandstone	0	1	42	0
Very dark green (almost black) igneous rock without any calcite.	7	0	49	0

The above section shows that the "agglomeratic tuff" gradually passes into the dark ultramafic igneous rock, and that the calcite veins grow lesser in number with depth and ultimately disappear altogether.

Some correctly labelled portions of the core from a borehole (No. 3) driven by the Syndicate were available in its office. A log from these fragments was prepared by the authors and is given in Table 11 below. This also shows the gradation of calcite-bearing "agglomeratic tuff" into calcite-free dark ultramafic igneous rock.

TABLE 11.

Section of borehole No. 3 at western edge of Balakhadan

(Present-day R. L. 72.78)

Description of rock	Thickness		Depth from surface	
	Ft.	In.	Ft.	In.
Concretions of clay	15	0	15	0
Clay with fragments of "agglomeratic tuff" .	3	0	18	0
Broken "agglomeratic tuff"	7	0	25	0
Dirty green "agglomeratic tuff" with horizontally disposed calcite stringers.	7	0	32	0
Darker "agglomeratic tuff" with horizontal calcite stringers.	8	0	40	0
Darker "agglomeratic tuff" with irregular calcite stringers.	5	0	45	0
Dark igneous rock with irregular calcite stringers.	20	0	65	0
Dark homogeneous rock	25	0	90	0
Dark fine-grained rock (no calcite) . .	85	0	175	0

APPENDIX A—contd.

It is also worth while to record here the sections of other boreholes driven by the Syndicate, although their logs are very sketchy. They at least serve the purpose of indicating the type of rocks through which they passed. They were located on the ground with the assistance of the Syndicate staff and put down on the plan of the Majhgawan deposit appended with this report (Plate 6). Their present-day R. Ls. were also noted, although they are likely to be slightly different from the actuals at the time of drilling. Since the difference is not expected to be more than a foot or two, this is no serious matter, particularly when the borehole logs themselves are approximate to the nearest foot.

Borehole No. 1 is the same as the one driven by K. P. Sinor near the temple well. Its section is given on page 54 of his monograph (1930).

The various records maintained by the Syndicate were incomplete and somewhat confusing. Based on inference, correlation of the data and the fragmentary core samples, a rough description of the rocks has been prepared and is given in Tables 12 to 19.

TABLE 12.

Section of borehole No. 2 on southern edge of Balakhadan.

(Present-day R. L. 58·25)

Description of rocks	Thickness Ft.	Total depth Ft.
Surface soil	10	10
?	25	35
"Agglomeratic tuff"	30	65
Dark igneous rock	145	210

TABLE 13.

Section of borehole No. 4 north-east of Balakhadan

(Present-day R. L. 71·39)

Description of rocks	Thickness Ft.	Total depth Ft.
Surface soil	85	85
"Agglomeratic tuff"	10	95
Dark igneous rock	125	220
Light blue material	33	153

APPENDIX A—contd.

TABLE 14.

Section of borehole No. 5 at the bottom of No. 2 quarry

(Present-day R. L. 64·95).

Description of rocks	Thickness Ft.	Total depth Ft.
Surface soil	65	65
"Agglomeratic tuff"	10	75
Dark igneous rock	45	120
Light blue material	33	153

TABLE 15.

Section of borehole No. 6 at the bottom of Rajakhadan

(Present-day R. L. 67·87).

Description of rocks	Thickness Ft.	Total depth Ft.
Surface soil	46	46
"Agglomeratic tuff"	17	63
Dark igneous rock	69	132

TABLE 16.

Section of borehole No. 7 about 300 ft. N. E. of Sinor's borehole No. 1

(Present-day R. L. not known as the hole could not be seen on the ground).

Description of rocks	Thickness Ft.	Total depth Ft.
Surface soil	16	16
Gravel	10	26
"Agglomeratic tuff"	21	47
Dark igneous rock	123	170

APPENDIX A—contd.

TABLE 17.

Section of borehole No. 9 about 300 ft. N. W. of Balakhadan

(Present-day R. L. 73·91).

Description of rocks	Thickness Ft.	Total depth Ft.
Surface soil	21	21
"Agglomeratic tuff"	21	43
Dark igneous rock	113	153

TABLE 18.

Section of borehole No. 11 on north edge of Bharakan

(Present-day R. L. 57·48).

Description of rocks	Thickness Ft.	Total depth Ft.
Surface soil	71	71
"Agglomeratic tuff"	10	81
Dark igneous rock	16	97
Light blue material	48	145

APPENDIX A—concld.

TABLE 19.

Section of borehole No. 12 about 250 ft. N. E. of Bharakan

(Present-day R. L. 69·48).

Description of rocks	Thickness Ft.	Total depth Ft.
Surface soil	50	50
"Agglomeratic tuff"	56	106
Dark igneous rock	19	125

In borehole Nos. 8 and 10, sandstone (indicated in the original record as "hard rock") was met with at 12 and 80 ft. respectively, under an overburden of alluvium.

It is not clear what is meant by light blue material in the section of Borehole Nos. 5 and 11. Unfortunately, the authors could not find any rock of this description in the heap of cores which would have enabled them to recognise it correctly.

APPENDIX B

Water Supply

A large quantity of water would be required in the milling process as well as for domestic purposes when large scale development of the mine takes place. It is, therefore, necessary to study the water-supply problem of the area in which the mine is situated. With this end in view a preliminary study of the groundwater conditions was carried out.

Water is available from two sources in this region, namely, (i) rain water impounded in tanks, and (ii) from wells by tapping the groundwater.

The preliminary groundwater studies show that the supply from this source alone would be adequate for domestic as well as industrial consumption for some time to come. The quality of water too is suitable. For a large industrial colony, it would perhaps be desirable to fit a water purification plant, because the chances of contamination would then increase. It may also be necessary to purify water for use in boilers when the need arises. This problem can be tackled at a later date when the expansion of mining activity makes it necessary to do so.

Groundwater.—The groundwater conditions within the igneous pipe are expected to be different from those in the sandstone country rock. However, the latter influence the conditions within the former to a very large extent, and the two must be studied together.

In the last week of January, 1956, the wells in the nearby Hinota village and in and around the Majhgawan pipe were studied, and samples collected for analysis. The data about the wells as well as those for Bharakan pit (which is a perennial repository of water) are tabulated in Table 20.

TABLE 20.

Data of wells in and around Majhgawan pipe

No.	Well or reservoir locality	Rock formation	R. L. of well collar Ft.	Depth of water level Ft.	R. L. of water level Ft.	Remarks
1.	Well, 2 furlongs N. W. of Hinota.	Sandstone	139·0	15·5	123·5	Perennial, regular use.
2.	*Baoli* well, 1 furlong east of Hinota.	do.	106·1	23·3	82·8	Dries up during summer.
3.	Rectangular well shaft near staff quarters.	do.	99·6	34·5	64·5	Perennial, irregular use.
4.	Circular well shaft in middle of pipe.	"Agglomeratic tuff"	80·3	27·7	52·6	Perennial, disused.
5.	Well near temple	do.	92·3	17·2	75 6	Do.
6.	Well, 400 feet north of temple.	Sandstone	94·0	20·0	74·0	Disused.
7.	Well, north of Balakhadan.	do(?)	96·0	8·0	88·0	do.
8.	Bharakan pit	"Agglomeratic tuff".	—	—	64·0	Perennial.

APPENDIX B—contd.

The tendency of water is to flow inward towards the centre of the pipe. Water from well No. 1 flows towards well No. 2 and then to well No. 3 which is situated close to the pipe boundary. The groundwater level in well No. 15, which is close to well No. 3 and in the expected direction of flow, is, however, higher by about 11 feet. This anomaly can possibly be explained by the fact that the former well is unused while the latter is the only source of supply to the whole mining camp and the low level is due to withdrawal of water. It may be mentioned here that the levels were taken in the afternoon by which time the water reservoir in the wells was bound to be less.

Well Nos. 6 and 7 are situated quite close to the pipe boundary, as are well Nos. 3 and 5 and the Bharakan pit. It is seen that the water from all these has a tendency to flow towards well No. 4 which is roughly in the centre of the pipe. This indicates that the flow is towards the middle of the pipe area, which acts as a sort of reservoir.

A point worth noting is that, although there is a steep scarp on the north-western part of this area, towards which the groundwater may be expected to flow, the flow of water is actually in the direction of the pipe. This is possibly due to the gentle dip of the sandstones away from the scarp which causes groundwater to flow south and eastward to the pipe. Since the pipe is at the foot of the Rewa scarp, the run-off water from its slope also flows into the basin in north and west directions.

Since the pipe acts as a kind of reservoir, the deposition of carbonates (mostly as calcite) has taken place in it, perhaps to a greater degree in the central zone of the pipe, because water from all sides tends to accumulate there. The deposition of calcite has been discussed in the chapter on "volcanic pipe".

Quality of Water.—The water required at Majhgawan is suitable for domestic consumption as well as industrial use. The samples of water from the various wells and from the Bharakan pit were analysed to find whether suitable qualities were available. The analyses are given in Table 21.

TABLE 21.

Analyses of water from wells in and around Majhgawan
(Figures given in parts per million)

Well No.	CO_3	HCO_3	Cl	SO_4	Fe less than	Total solids at 180° C	pH at 31° C
1.	48	492	44	3·7	0·2	484	8·60
2.	12	165	59	19·3	0·2	368	8·45
3. (i)	Nil	189	42	12·3	0·2	292	7·68
*3. (ii)	Nil	195	39	13·9	0·2	272	7·93
4.	54	411	62	10·2	0·2	524	8·20
5(i).	30	356	32	7·4	0·2	432	8·12
*5. (ii)	36	343	33	11·5	0·2	384	8·28
6.	24	245	33	trace	0·2	332	7·75
7.	23	270	17	trace	0·2	216	8·18
8. (i)	30	250	29	5·3	0·2	300	8·21
*8. (ii)	18	251	32	4·9	0·2	292	7·60

* Duplicate samples obtained in neutral glass bottles. Remaining samples collected in ordinary bottles.

APPENDIX B—contd.

The analyses also indicate the general trend of the movement of water towards the centre of the pipe. The hardness of water progressively decreases from well No. 1 to well No. 2, being the lowest in well No. 3; all the wells are in sandstone. The hardness is greater in the water of the pipe area than in the water contained in the sandstone, because some calcite and other carbonate minerals occur in the pipe rock. Among the wells within the pipe limit, the maximum hardness of water is in the central well No. 4, which is roughly in the spot where all the water tends to accumulate. The increase of carbonates and bicarbonates in the central portion of the pipe is due to the concentration of water there. The low bicarbonate in the Bharkan pit may be due to the dilution from water infiltering from the nearby sandstone.

The same general pattern is shown by the chloride content. It is maximum in well No. 4 as expected. The only anomaly occurs between well Nos. 1 and 2. Chloride in the former ought to be more than in the latter, but actually it is the reverse, possibly because of contamination from the village of Hinota.

Similarly, the sulphate content decreases progressively towards the centre of the pipe area, but in the centrally situated well No. 4 it is higher due naturally to dilution.

The water found in the country rock, as well as in the pipe itself, is suitable for both domestic and industrial purposes. No bacteriological tests were made, and it is difficult to say whether any harmful bacteria are present. It may, however, be remarked that the water of well No. 3 was used by the camp as well as by the villagers.

For drinking water any constituent in an amount perceptible to taste is objectionable. 150 to 500 parts per million of mineral content is moderate and can be accepted for drinking and the total solids in these samples are within the permissible limits, except in the case of well No. 4, in which they are only slightly higher. As little as 0.5 part of iron per million is detectable by taste and 1.5 parts per million is the limit for drinking. Since these samples contain less then 0.2 part per million of iron, all are palatable. According to the U.S. Geological Survey, soft water should have 50 to 100 parts of calcium carbonate per million,and all the waters analysed therefore are soft.

The quality of water for manufacturing purposes depends upon the use to which it is to be put. If the dissolved or suspended mineral matter is such that it forms scales or causes corrosion, the water becomes unsuitable for use in boilers. Since there are no boilers yet in use at the mines, this question does not arise at present ; but if at a later date boilers are to be used, it is expected that some of the water tested will be suitable for the purpose.

The largest use of water in the mill is for washing the pans and other machines. All the water analysed has been found to be suitable for this purpose.

Quantity of water.—It is reported that well No. 1 is perennial and meets the entire requirements of Hinota village. Well No. 3 is also perennial and, since it is in the mine camp, is the most used. It was actually a 11 ft. ×5 ft. rectangular mine shaft in the past and is 110 feet deep. At present its normal capacity is about 30,000 gallons. This would supply a mine camp of about 1,500 at a daily consumption of 20 gallons per head. The water drawn during the day is expected to be replenished during the night. At present water is drawn only by hand-bucket. Since this well is situated in the country rock and will not be disturbed during mining of the deposit, it can be an important source of water-supply in this locality. If need be, it can be enlarged suitably, because it appears to be situated at a favourable spot.

No estimates have been made about the quantity of water available from the pipe area itself. But it is believed that the supply would be adequate, at least during the rainy and winter seasons. The water from the pits can be pumped out into reservoirs and stored for use during the summer months. As a matter of fact, one such reservoir has already been built by the Syndicate.

APPENDIX C

Description of Sampling Shafts

Pit No. 1. (R.L. 72.06).—This was originally started as an open quarry 30 × 10 ft. on the surface. When it had gone to a depth of 14.5 ft. it was stopped, because on the advice of the Russian specialists it was decided to sink 8×6 ft. shafts instead of open pits. An 8×6-foot pit was later sunk on the eastern flank of the open pit up to a depth of 10 ft. to take out the alluvial overburden sample and it was intended to sink a shaft at this site. It was finally decided to revert to the original open pit for taking out the main "agglomeratic tuff" sample because of difficulty in sinking a shaft. "Agglomeratic tuff" was met with at the depth of 22 ft. 2 in., when the section of the pit was reduced to the standard 8×6 ft. The 40-ton sample was obtained by going 12.5 ft. further down. The "agglomeratic tuff" was khaki-green in colour and very compact and hard, and was traversed by a network of calcite veins. Twelve diamonds weighing 5.23 carats were found.

Shaft No. 2. (R.L. 73.11).—This shaft was sunk to a depth of 24 ft. "Agglomeratic tuff" *in situ* was met with at 12 ft. depth under an overburden consisting of earth containing loose pieces of "agglomeratic tuff". For about 6.5 ft. the *in situ* rock was somewhat soft, but became very hard and compact deeper down. It gave three diamonds weighing 2·59 carats.

Shaft No. 3. (R.L. 74.32).—This shaft went down to a depth of 22.5 ft., out of which the last 12.5 ft. was in hard "agglomeratic tuff", which yielded six diamonds weighing 8.86 carats. About 30 tons of the alluvial overburden was also treated, and four diamonds weighing 1·23 carats were recovered.

Shaft No. 4 (R.L. 75.56).—"Agglomeratic tuff" in this shaft was encountered at 28.5 ft. depth from the surface, and the shaft was sunk 41 ft. deep. The rock was compact with weathered layers intermixed along the horizontal joint planes, and its usual 40-ton sample proved barren of diamond. The alluvial overburden consisted of reworked waste containing fine gravel and *kankar* with a few loose "agglomeratic tuff" blocks.

Shaft No. 5. (R.L. 79.72).—Reworked waste containing gravel was found up to a depth of about 5 ft. Beneath it there was compact soil up to 20 to 25 ft. in an irregular layer. Tuffaceous clay of dark colour with some veins of serpentine and some rounded patch-like inclusions of shale, six to nine inches in size, were found beneath the soil. Some quartz, possibly occurring as veins and small lenses, was found in the dark tuffaceous clay. The pit was taken to the depth of 46 ft. 8 in. A 75-ton sample of this tuffaceous material was treated for diamonds, and a single small stone was recovered.

Shaft No. 6. (R.L. 83.18).—Soil was met with up to a depth of 8 ft. in the original 8×6 ft. shaft. In order to obtain a 40-ton sample of this soil the length of this pit was increased by 6.5 ft. giving an area of 8×12½ ft. About 5 tons of this sample was treated without any success.

Highly fragmented shales of green and chocolate colour, lithologically like the Jhiri Shale, were met with under the soil overburden. These shales occurred on the northern and eastern portion of the shaft, while on the remaining sides a calcareous, clay-like, highly altered tuff was encountered under a thin band of shale. The contact between the tuff and shale was quite sharp, though irregular, and dipped about 75° towards east. Some calcite concretions were also seen in the shales indicating that the calcareous matter was introduced after the deposition of the shale. Soft tuff of light colour with darker patches was met with from the depth of 22 ft. The shaft went down to a depth of 34 ft. 4 in., and a 98-ton sample of the mixed material was treated with the recovery of two diamonds weighing 1·35 carats.

Shaft No. 7. (R.L. 87·47).—Beneath a gravelly soil overburden of 3 to 4 ft., a roughly laminated, yellowish brown, compact, highly ferruginous sandstone was found in the shaft up to a depth of about 18 ft. This material was thought to be a ferruginous "agglomeratic tuff" by the Russians, and they got it treated in the mill. No diamond was found.

Underlying it was found a thin-bedded, compact sandstone with interbedded sandy, micaceous shale up to the depth of 25 ft. This sandstone was white in colour with some pinkish patches, and the shale was greenish with red bands. Their attitude was horizontal.

Shaft No. 8. (R.L. 77·80).—This shaft was sunk to the depth of 41 ft. 2 in. without meeting compact "agglomeratic tuff". Refilled clay with pieces of "agglomeratic tuff" and sandstone was found up to the depth of 12 to 15 ft., and under its irregular boundary were found shale and disintegrated tuff. The two occurred intermixed and their exact inter-relationship was not clear. Some tuff contained inclusions of shale while in other cases lenticles of tuff occurred within the shale. White calcareous bands were scattered within this mass. Seventy-five tons of this material was taken for milling, and a single half-carat diamond was obtained.

Shaft No. 9. (R.L. 90·71).—Beneath a gravelly top soil of 3 ft. there occurred a gravel bed consisting of chips and small fragments of sandstone derived from the *in situ* disintegration of the Kaimur sandstone, which occurred at 6·5 ft. depth and was excavated for another 1·5 ft. It was thin-bedded and somewhat fragmented, and dipped roughly 10° towards the north-east.

Shaft No. 10. (R.L. 75·49).—This shaft was sunk to the depth of 26 ft. The top portion consisted of clay containing a good deal of "agglomeratic tuff" and of the lower of compact and hard ultramafic rock. Since the boundary between the two was irregular, an average of 13·5 ft. of "agglomeratic tuff" was taken for the 40-ton sample. Four diamonds weighing 5·42 carats were recovered.

Shaft No. 11. (R.L. 87·94).—There was clay for the first 6·5 ft., out of which the top five ft. appeared to be refilled waste. Separated from

APPENDIX C—contd.

the overburden by a clear-cut boundary there was calcareous soil for about 9·5 ft., under which there was four to six ft. of tuffaceous matter containing purple and green shale inclusions. Soft, mottled tuff was found under the irregular boundary of tuffaceous matter up to the bottom of the shaft at 33·5 ft. These various types of rocks graded into one another. All the material below the 6·5 ft. depth, weighing 75 tons, was sampled, but did not yield any diamond.

Shaft No. 12. (R.L. 70.87).—Worked out alluvium consisting of laminated clay and gravelly material was found up to the depth of 32 ft. 10 in. Beneath this, up to 40·5 ft. was found soft "agglomeratic tuff", which crumbled easily upon exposure to the atmosphere. This rock was characterised by almost complete absence of calcite veins and nodules. Much brown mica was present, and it contained some dark coloured inclusions of the type found in the hard and compact variety. The easy disintegration of this rock was also responsible for diamonds coming loose from the rock and being picked up while transporting the sample. Ten diamonds weighing 5·66 carats were recovered.

Shaft No. 13. (R.L. 82·81).—Under an overburden of refilled waste, 48 ft. thick, a sample of 40 tons of a material which defies easy labelling was obtained. It consisted of a dark coloured, soft, earthy shale, some greenish shale, and some mottled, brownish and greenish tuffaceous material, with conspicuous absence of any calcareous matter. The shaft went down to the depth of 61·5 ft. and was the deepest sunk during the sampling operations. The sample from this shaft did not yield any diamond.

Shaft No. 14 (R.L. 74.13)—Up to 36 ft. from the surface various types of refilled clays were met with. They were laminated brownish, greenish and dark coloured. Below these, "agglomeratic tuff" was found up to the depth of 52 ft. This rock was mostly very soft and disintegrated easily upon exposure to atmosphere, but some hard and compact portions were also found. The little calcite seen was irregularly distributed and not horizontally disposed as in the compact and hard "agglomeratic tuff". Five diamonds weighing 4.68 carats were obtained from the usual sample.

Shaft No. 15. (R.L. 72.95).—Smooth clay with a narrow layer of gravel at the surface occurred up to the depth of about 18.5 ft. Below this was a small two-foot layer of broken "agglomeratic tuff" blocks with a few small sandstone pieces. Underneath was a little weathered "agglomeratic tuff" and then hard and compact variety with calcite veins up to the depth of 31 ft. The 40-ton sample yielded 4 diamonds weighing 1.41 carats.

Shaft No. 16 (R.L. 63.05).—Under 13.5 ft. of refilled gravelly waste occurred a very compact "agglomeratic tuff" up to the depth of 26ft. The rock from this shaft was of considerable interest, because it contained a large number of ferruginous and diabase-like inclusions, and much brown mica. It was the most prolific producer of diamonds, as the usual sample gave a recovery of 19 stones weighing 12.13 carats.

APPENDIX C—concld.

Shaft No. 17.—It could not be sunk, because it was situated within the Bharakan pit, which was filled with water that made working impossible.

Shaft No. 18. (R. L. 76.67)·—Up to the depth of 20 ft. it was full of clay with many embedded blocks of "agglomeratic tuff" and sandstone. Below this were found masses of a hard siliceous rock with some shale and altered tuff in clay up to the depth of 31 ft., after which compact sandstone and shale were encountered to the depth of 40.5 ft. from the shaft collar. This rock was highly disturbed in the lower portion, the beds being fractured and crumbled.

Shaft No. 19. (R.L. 67.03).—This shaft was sunk up to the depth of 29 ft. The last 2 ft. were in micaceous sandstone and shale, and the remaining in clay.

Shaft No. 20. (R.L. 74.41).—It was sunk to a depth of 43 ft. 4 in. entirely in alluvium. At about 40 ft. depth a little dark coloured, possibly tuffaceous material was obtained with the clay. It is possible that if the shaft had gone down only a few feet deeper, "agglomeratic tuff" would have been found. However, the shaft had to be abandoned, because in spite of double lining of timber it started to collapse.

Shaft No. 21. (R.L. 85.12).—Clay with pieces of "agglomeratic tuff" and shale was found up to the depth of 25 ft. Beneath this, up to 30.5 ft. occurred a hard, laminated shale with intercalations of sandstone 6 to 8 in. thick. The shale was similar to the Jhiri Shale, and the sandstone like intercalations in the Jhiri found elsewhere in this field.

APPENDIX D

Description of Experimental Trenches

Trench A.—Size, 22 ft. ×3 ft. ×7 ft. to 9½ ft. This was started about 200 ft. south of Shaft No. 9 in order to determine the pipe boundary. It lies outside, because disintegrated gravel like sandstone was found at about 6 to 7 ft. depth under a gravelly soil containing broken sandstone pieces.

Trench B.—Size, 15¾ ft. ×3 ft. ×9½ ft. It was situated about 75 ft. west of the temple well. At about 7½ ft. depth a calcareous soil, like that found in sampling Shaft No. 11 was found. It was, therefore, inferred that it fell within the pipe limit.

Trench C.—Size, 12 ft. ×3⅓ ft. ×8 ft. It was located about 80 ft. south-west of the temple well. Under a banded clay and gravel, and irregular surface from 4 to 7 ft., the same calcareous clay as seen in Shaft No. 11 was found, showing that it lay within the limit of the pipe.

Trench D.—Size, 30 ft. ×3½ ft. ×9 ft. It was situated about 120 ft. south of sampling Shaft No. 11. Gravelly material derived from the disintegration of sandstone was found in the trench under about five feet of gravelly soil. In one part of the trench flaggy sandstone was also exposed.

Trench E.—Size, 16 ft. ×3 ft. × 5 to 7 ft. It was located about 90 ft. W. S. W. of Shaft No. 21 near a sandstone outcrop. Large blocks of sandstone were found in the trench, showing that it lay beyond the pipe limit.

Trench F.—Size, 27 ft. ×3½ ft. × 2 ft. sloping to 10½ ft. This was dug at about 100 ft. S. S. E. of Shaft No. 21 in order to find the contact. Sandstone was met with at the bottom of the trench.

Trench G.—Size, 9½ ft. × 3½ ft. × 5½ ft. It was situated about 50 ft. south of Shaft No. 9. Flaggy sandstone was met with from 3½ ft. to 5½ ft. depth. It was overlain by about 2 ft. of gravelly material formed by disintegration of sandstone. Soil formed the uppermost layer near the sufrace.

Trench H.—Size, 27 ft. × 3 ft. × 5½ ft. to 10½ ft. It was dug to the north-west of Shaft No. 7 to locate the boundary. A large quantity of small sized gravel, obviously the tailings from diamond washing, was found in the trench. In the northern portion yellow disintegrated sandstone was met with, and the trench was full of embedded sandstone blocks indicating that it was outside the pipe area.

Trench I and N.—Size, 35 ft. × 3 ft. × 10 ft. A 10.5-foot long trench was first started about 25 ft. north-west of Trench B, and another 8-foot long trench was dug about 15 ft. north-west of the above, marked I and N, respectively. Later, the two were joined up. Disintegrated gravelly material was met with in this trench, but at the bottom for

APPENDIX D—*contd.*

about six inches a calcareous clay like that exposed in Shaft No. 11 was found, and, therefore, it was included within the pipe limit.

Trench J.—Size, 13 ft. × 2½ ft. × 11 ft. It was dug about 90 ft north of sampling Shaft No. 5. A small portion of disintegrated sandstone was found in the northern portion at a depth of about 7 ft. and therefore, it was put outside the pipe boundary.

Trench K.—Size, 9 ft. × 3 ft. × 11⅓ ft. This was situated about 50 ft. north of Trench T. Under about three feet of alluvium, gravelly material derived from the disintegration of sandstone together with highly fragmented and rudely bedded sandstone was met with up to the bottom of the trench.

Trench L.—Size, 14 ft. × 3¼ ft. × 11½ ft.. maximum. It was dug about 175 ft. south of Trench M, and about 100 ft. south-west of Trench C, because tuffaceous soil was found in these and it was suspected that the pipe extended in their direction. This conjecture proved correct, as under an overburden of about 6 ft. of soil, a white tuffaceous clay, like the one found in sampling Shaft No. 11, was found for about five feet. It appears, therefore, that the pipe extends in this direction as a narrow projection.

Trench M.—Size, 7½ ft. × 3½ ft. × 4 ft. I was dug between Trenches A and G to confirm the occurrence of sandstone in this part of the area. Large blocks of sandstone together with gravelly material derived from its disintegration were seen.

Trench O.—Size, 34 ft. × 4 ft. × 5 ft. to ft. It was placed about 130 ft. S. S. E. of Shaft No. 13 at the suspected sandstone limit. The entire trench was in alluvium, except for its south-western end where massive sandstone formed an abutment. The slope of this sandstone face was about 75° on top decreasing to about 45° at the bottom. The boundary of the pipe was drawn along the sandstone exposure.

Trenches P and Q.—Size of P, 18 ft. × 4½ ft. × 7½ ft., and of Q, 13½ ft. × 4½ ft. × 6½ ft. They were placed about 250 and 225 ft. S.S.W. of sampling Pit No. 1 in an attempt to expose the country rock, because no rock outcrop was seen for about 100 ft. around. However, they were full of alluvium only.

Trench R.—Size, 14 ft. × 3 ft. × 8 ft. When Trench H did not show any sandstone contact, it was decided to place a trench about 25 ft. away from Shaft No. 7. Gravelly soil together with sandstone blocks was found in this trench, also. The conclusion was that it fell outside the boundary of the pipe.

Trench S.—Size, 19½ ft. × 2½ ft. × 15 ft. It was located about 125 ft. north-east of the first location of Shaft No. 14. Although it went down 15 ft. deep, no solid rock was exposed. Alluvium containing blocks of " agglomeratic tuff " and sandstone showed that it occurred just near the pipe boundary.

APPENDIX E

Detailed Shaft-wise Production

In Tables 22 to 40 the details of production from each shaft are given. This information is tabulated here to serve as a permanent record. The weight of the diamond is given in *rattis* in these tables as recorded in the Diamond Office. A *ratti* is divided into sixteen parts and each part is called an '*anna*'. When a diamond is taken to the Diamond Office it is not only weighed but its approximate value is estimated and a detailed physical examination made. It is said that each stone has its own characters and from the description it can be recognised distinctly by an expert from among thousands of other diamonds. The terminology used by the Panna jewellers is given below with English explanation :

COLOUR—

Ujjwal	Lustrous.
Ghia-pani	Frosted.
Awwal-Pani	Perfect white.
Pire-pani or (Pile-pani)	Yellowish tinge.
Hare-pani	Greenish tinge.
Nile-pani	Bluish tinge.
Maile-Pani	Darkish colour.
Mattho	Blackish or brownish dark bort.

FORM—

Ashtang	Octagonal.
Gol	Roundish.
Chapto	Flattish.
Lambo	Elongated.
Samuro	Cleaved.
Trikon	Triangular.
Bilki	Twin.
Patkan	Undulated surface.
Garan	Surface with depression.
Chikno	Smooth surface.

INCLUSIONS—

Chhinta	Big black spot.
Dhunnan	Minute black spot.
Bulla	Bubble-like inclusion.
Jiram	Inner crack.
Kag-bidar	Black, bird-like inclusion.
Rakt-bidar	Red inclusion, either a dot or a line.
Jal	Network of kawas.

The jewellers in the Diamond Office also make an appraisal of value of each diamond deposited. This is kept confidential and serves as a guide during auction. This valuation is important, because any scheme for exploitation and development must take into account the monetary value of the gems and not the weight alone.

APPENDIX E—*contd.*

TABLE 22.

Production from sampling Shaft No. 1

Lithology of sample : Hard and compact " agglomeratic tuff ".

Weight of sample—40 tons.

Serial No.	Weight in *Rattis.*	Estimated rate per *Ratti.*	Approx. value.		Description (based on local terminology).
	Ra. An.	Rs.	Rs.		
1.	2 3	40	87 ·50	Industrial .	*Mattho, Chapto Lambo Samuro, Garhan, Patkan, Jirman, Chhintan, Dhumarandar.*
2.	0 1	40	2 ·50	Industrial .	*Mattho, Chapto, Lambo. Samuro, Jirman, Chhintandar.*
3.	1. 0	100	100 ·00	Cuttable gem	*Ujjwal, Chapto, Lamberukh, Chikono, Chhintandar.*
4.	0 10	150	93 ·75	Cuttable gem	*Ujjawal, Chapto, Lambo.*
5.	0 7	40	17 ·50	Cuttable gem	*Peerepani, Chapto, Lambo, Garh, Patak, Chhintandar.*
6.	0 4	40	10 ·00	Industrial .	*Mattho, Chapto, Samuro, Garhandar.*
7.	0 4	40	10 ·00	Industrial .	*Mailepani, Samuro, Garhan, Chhintan, Dhumarandar.*
8.	0 3	40	7 ·50	Industrial .	*Mattho, Chapto, Garh, Jirmandar.*
9.	0 2	40	5 ·00	Industrial .	*Mattho, Chapto, Garhan, Chhintandar.*
10.	0 1	40	2 ·50	Industrial .	*Mattho, Chapto, Lambo, Samuro, Dhumrandar.*
11.	0 1	40	2 ·50	Industrial .	*Mailepani, Chapto, Samuro, Trikonrukh, Dhumarandar.*
12.	0 1	30	1 ·88	Industrial .	*Mattho, Chapto, samuro Garhandar.*
Total .	5 5		340 ·62		

APPENDIX E—*contd.*

TABLE 23.

Production from sampling Shaft No. 2.

Lithology of sample : Hard and compact " agglomeratic tuff ".
Weight of sample—40 tons.

Serial No.	Weight in *Rattis*.	Estimated rate per *Ratti*.	Approx. value.	Quality.	Description (based on local terminology).
	Ra. An.	Rs.	Rs.		
1.	1 6	60	82 ·50	Cuttable gem	*Ujjwal, Chapto, Tricone, Garhan, Chitan, Dhumran, Barsome. Katdar, Bilki.*
2.	0 8	150	75 ·00	Cuttable gem	*Ujjwal, Chapto, Asthang, Chintto, Jirman, Dhumrandar.*
3.	0 12	200	150 ·00	Cuttable gem	*Ujjwal, Asthang, Samoro Jirman, Dhumrandar, Kamharepani.*
Total	2 10		307 ·50		

TABLE 24

Production from sampling Shaft No. 3:

Lithology of sample. : Hard and compact " agglomeratic tuff."
Weight of sample—40 tons.

Serial No.	Weight in *Rattis*.	Estimate rate per *Ratti*.	Approx. value.	Quality.	Description (based on local terminology).
	Ra. An.	Rs.	Rs.		
1.	1 1	80	85·00	Industrial .	*Mailepani, Chapto, Ashtang, Dhumrandar.*
2.	0 10	30	18·75	Industrial .	*Mattho, Chapterukh, Samuro, Garhan, Chinte, Dhuran, Jiramdar.*
3.	3 15	700	2,756·25	Cuttable gem	*Ujjwal, Chapto, Lamberukh, Ashtang, Dhumrandar.*
4.	2 2	40	85·00	Industrial .	*Mattho, Piro, Chapto, Lambo, Garhan, Chinte, Dhumrandar.*
5.	1 3	40	47·50	Industrial .	*Mailepirepani, Chapto, Lambo, Garhan, Chintan., Jiramdar.*
6.	0 1	30	1·88	Industrial .	*Mattho, Chapto, Lambo, Garhandar.*
	9 0		2,994·37		

APPENDIX E—*contd.*

TABLE 25.

Production from sampling Shaft No. 3.

Lithology of sample. : Alluvium (Overburden)

Weight of sample—30 tons.

Serial No.	Weight in *Rattis*.	Estimated rate per *Ratti*.	Approx. value.	Quality.	Description (based on local terminology).
	Ra. An.	Rs.	Rs.		
1.	0 5	40	12·50	Industrial	*Pirepani, Chapto, Lambo, Garhandar.*
2.	0 1	30	1·87	Industrial	*Mattho, Chapto, Lambo, Garhandar.*
3.	0 8	180	90·00	Cuttable gem	*Ujjwal, Chapto, Lambo, Garhan, Patkan, Dhumrandar.*
4.	0 6	30	11·25	Industrial	*Mattho, Chapto, Lambo, Garhan, Patkan, Dhumrandar.*
Total	1 4		115·62		

TABLE 26.

Production from sampling Shaft No. 4.

Lithology of sample : Hard and compact "agglomeratic tuff".

Weight of sample—40 tons.

Serial No.	Weight in *Rattis*.	Estimated rate per *Ratti*.	Approximate value.	Quality.	Description (based on local terminology),

NO DIAMOND RECOVERED

APPENDIX E—*contd.*

TABLE 27.

Production from sampling Shaft No. 5.

Lithology of sample : Tuffaceaus clay.

Weight of sample—75 tons.

Serial No.	Weight in *Rattis.*	Estimated rate per *Ratti.*	Approximate value.	Quality.	Description (based on local terminology).
	Ra. An.	Rs.	Rs.		
1.	0 1	40·00	2·50	Industrial	*Pirepani, Chapto, Lambo, Samuro, Dhumarandar.*
Total	0 1		2·50		

TABLE 28.

Production from sampling Shaft No. 6.

Lithology of sample : Disintegrated tuff with shale.

Weight of sample—75 tons.

Serial No.	Weight in *Rattis.*	Estimated rate per *Ratti.*	Approximate value.	Quality.	Description (based on local terminology).
	Ra. An.	Rs.	Rs.		
1.	1 5	40·00	52·50	Industrial	*Mattho, Chapto, Lambo, Garhan, Patkan.*
2.	0 1	64·00	4·00	Cuttable gem	*Ujjwal, Chapto, Lambo, Tricon-rukh, Pat-kandar.*
Total	0 1		56·50		

APPENDIX E—*contd.*

TABLE 29.

Production from sampling Shaft No. 6.

Lithology of sample : Alluvium (Overburden).

Weight of sample—5 tons.

Serial No.	Weight in *Rattis.*	Estimated rate per *Ratti.*	Approximate value.	Quality.	Description (based on local terminology).
NO DIAMOND RECOVERED					

TABLE 30.

Production from sampling Shaft No. 7.

Lithology of sample : Ferruginous, weathered sandstone.

Weight of sample—40 tons.

Serial No.	Weight in *Rattis.*	Estimated rate per *Ratti.*	Approximate value.	Quality.	Description (based on local terminology).
NO DIAMOND RECOVERED					

NOTE—This was treated in the mill at the instance of the Russian geologists who thought that this material was ferruginous "agglomeratic tuff".

TABLE 31.

Production from sampling Shaft No. 8.

Lithology of sample : Disintegrated tuff with shale.

Weight of sample—75 tons.

Serial No.	Weight in *Rattis.*	Estimated rate per *Ratti.*	Approximate value.	Quality.	Description (based on local terminology).
	Ra. An.	Rs.	Rs.		
1.	0 9	30·00	16·87	Industrial	*Mattho, Chapto Samuro, Garhandar.*
Total	0 9		16·87		

APPENDIX E—*contd.*

TABLE 32.

Production from sampling Shaft No. 10.

Lithology of sample : Hard and compact "agglomeratic tuff".

Weight of sample—40 tons.

Serial No.	Weight in *Rattis.*	Estimated rate per *Ratti.*	Approximate value.	Quality.	Description (based on local terminology).
	Ra. An.	Rs.	Rs.		
1.	0 12	150·00	112·50	Cuttable gem	*Ujjwal, Chapto, Lambo, Ashtang, Dhumarandar.*
2.	0 15	30·00	28·12	Industrial	*Mattho, Chapto, Lambo, Garhan, Jirman, Vingaram, Chinte, Dhumarndar.*
3.	2 14	40·00	115·00	Industrial	*Mattho, Chapto, Gol, Garhan, Vingaram, Chinte, Dhumrandar.*
4.	0 15	125·00	117·00	Cuttable gem	*Ujjwal, Chapto, Lamberukh, Garhan, Chitan Dhumrandar.*
Total	5 8		372·62		

TABLE 33.

Production from sampling Shaft No. 11.

Lithology of sample : Highly altered tuff with clay and a little shale.

Weight of sample—74 tons.

Serial No.	Weight in *Rattis.*	Estimated rate per *Ratti.*	Approximate value.	Quality.	Description (based on local terminology).
NO DIAMOND RECOVERED					

APPENDIX E—*contd.*

TABLE 34.

Production from sampling Shaft No. 12.

Lithology of sample : Soft "agglomeratic tuff".

Weight of sample—40 tons.

Serial No.	Weight in *Rattis.*		imated rate per *Ratti.*	Approximate value.	Quality.	Description based on local teerminology).
	Ra.	An.	Rs.	Rs.		
1.	0	5	50·00	40·62	Cuttable gem	*Ujjawl, Chapto, Lamerukh, Ashtang, Dhumrandar.*
2.	1	32	50·00	50·37	Cuttable gem	*Ujjwal, Chapto, Lambo, Ashtang, Chintan, Jal, Vingaramdar.*
3.	0	12	100·00	75·00	Cuttable gem	*Ujjwal, Chapto, Lamberukh, Garhan, Patkan, Dhamrandar.*
4.	0	3	30·00	5·62	Industrial	*Mattho, Chapto, Samuro, Garhandar.*
5.	0	13	40·00	32·50	Industrial	*Mattho, Chapto, Lambo, Samuro, Garhan, Chintandar.*
6.	0	5	160·00	50·00	Cuttable gem	*Ujjwal, Chapto, Lambo, Patakdar.*
7.	1	3	40·00	47·50	Industrial	*Mattho, Chapto, Lamberukh, Garhan, Dhumrandar.*
8.	0	11	60·00	11·25	Cuttable gem	*Ujjwal, Chapto, Lamerukh, Garhan, Chinton, Dhumrandar.*
9.	0	3	30·00	5·62	Industrial	*Mattho, Piro, Chapto, Lambo, Garhan, Dhumrandar.*
10.	0	2	30·00	3·75	Industrial	*Mattho, Chapto, Lambo, Samuro, Garhan, Chintandar.*
Total	5	12		361·23		

APPENDIX E—*contd*

TABLE 35.

Production from sampling Shaft No. 13.

Lithology of sample : Dark clay shale with tuffaceous material.

Weight of sample—40 tons.

Serial No.	Weight in *Rattis.*	Estimated rate per *Ratti.*	Approximate value.	Quality.	Description (based on local terminology).
NO DIAMOND RECOVERED					

TABLE 36.

Production from sampling Shaft No. 14.

Lithology of sample : Soft "agglomeratic tuff".

Weight of sample—40 tons.

Serial No.	Weight in *Rattis.*		Estimated rate per *Ratti.*	Approximate value.	Quality.	Description (based on local terminology).
	Ra.	An.	Rs.	Rs.		
1.	1	11	300·00	506·25	Cuttable gem	*Ujjwal, Chapto, Lamerukh, Ashtang, Chinte, Dhumrandar.*
2.	0	9	130·00	73·12	Cuttable gem	*Ujjwal, Chapto, Lambo, Garhan, Chintandar.*
3.	0	13	100·00	81·25	Cuttable gem	*Ujjwal, Chapto, Dhumrandar, Kamjardi.*
4.	0	13	60·00	48·75	Cuttable gem	*Ujjwal, Jardipani, Garhan, Chintan, Dhumrandar, Chaptorukh.*
5.	0	14	80·00	70·00	Cuttable gem	*Ujjwal, Chapto, Lambo, Chinten, Dhumrandar, Kamjardi.*
Total	4	12		779·37		

APPENDIX E—*contd.*

TABLE 37.

Production from sampling Shaft No. 15.

Lithology of sample : Hard and compact "agglomeratic tuff".

Weight of sample—40 tons.

Serial No.	Weight in *Rattis.*		Estimated rate per *Ratti.*	Approximate value.	Quality.	Description (based on local terminology).
	Ra.	An.	Rs.	Rs.		
1.	0	3	200·00	162·50	Cuttable gem	*Ujjwal, Chapto, Garhan, Dhumrandar.*
2.	0	8	40·00	20·00	Industrial	*Mattho, Chapto, Samuro, Garhan, Dhumrandar.*
3.	0	1	64·00	4·00	Cuttable gem	*Ujjwal, Chapto, Lambo, Dhumrandar.*
4.	0	1	45·00	2·81	Cuttable gem	*Ujjwal, Pirepan, Chapto; Lambo, Garhan, Chintandar.*
Total	1	7		189·31		

TABLE 38.

Production from sampling Shaft No. 16.

Lithology of sample : Hard and compact "agglomeratic tuff".

Weight of sample—40 tons.

Serial No.	Weight in *Rattis.*		Estimated rate per *Ratti.*	Approximate value.	Quality.	Description (based on local terminology).
	Ra.	An.	Rs.	Rs.		
1.	0	1	64·00	4·00	Cuttable gem	*Ujjwal, Chapto, Lambo.*
2.	2	9	40·00	102·50	Industrial	*Mattho, Chapto, Lambo, Treconemukh, Garhan, Patcan, Jirman, Chintan, Dhumrandar.*

APPENDIX E—*contd.*

TABLE 38—*contd.*

Serial No.	Weight in *Rattis*.		Estimated rate per *Ratti*.	Approximate value.	Quality.	Description (based on local terminology).
	Ra.	An.	Rs.	Rs.		
3.	1	9	100·00	234·37	Cuttable gem	*Ujjwal, Chapto, Lambo, Garhan, Patak, Chintan, Dhumrandar.*
4.	1	1	100·00	106·25	Cuttable gem	*Ujjwal, Chapto, Ashtang, Chintandar.*
5.	0	10	40·00	25·00	Cuttable gem	*Ujjwal, Pilapani, Chapto, Lamberukh, Garhan, Patakdar.*
6.	0	4	30·00	7·50	Industrial	*Mailepani, Chapto, Lambo, Samuro, Garh, Jirman, Dhumrandar.*
7.	0	3	30·00	5·62	Industrial	*Pirapani, Chapto, Lambo, Garhan, Dhumrandar.*
8.	1	1	200·00	212·50	Cuttable gem	*Ujjwal, Chapto, Lambo, Rukh, Dhumrandar.*
9.	0	4	40·00	10·00	Industrial	*Mattho, Chapto, Garhdar.*
10.	1	3	80·00	95·00	Cuttable gem	*Ujjwal, Chapto, Lambo, Garhan, Jirman, Chintandar.*
11.	0	14	40·00	35·00	Industrial	*Mailepani, Chapto, Samuro, Garhan, Patkan, Jirman, Dhumrandar.*
12.	0	9	40·00	22·50	Industrial	*Mattho, Chapto, Lambo, Garhan, Patkan, Jirman, Chintandar.*
13.	0	8	45·00	22·50	Cuttable gem	*Pirepani, Chapto, Samuro, Garhan, Pitkan, Chintan, Jiramdar.*

APPENDIX E—*contd.*

TABLE 38—*concld.*

Serial No.	Weight in *Rattis.*		Estimated rate per *Ratti.*	Approximate value.	Quality.	Description (based on local terminology).
	Rs.	As.	Rs.	Rs.		
14.	0	8	40·00	20·00	Industrial	*Mattho, Chapto, Samiro, Jaldar.*
15.	0	3	40·00	12·50	Industrial	*Mattho, Chapto, Samuro, Trekon, Rukh, Jiram, Chintandar.*
16.	0	2	40·00	5·00	Industrial	*Mailepani, Chapto, Samuro, Chinton, Dhumrandar.*
17.	0	1	40·00	2·50	Industrial	*Mattho, Chapto, Samuro, Garhan, Patkan, Chintan, Dhumrandar.*
18.	0	1	40·00	2·50	Industrial	*Mattho, Chapto, Samuro, Dhumrandar.*
19.	0	8	50·00	25·00	Cuttable gem	*Ujjwal, Mailepani, Chapto, Lambo, Garhan, Patkan Chintandar.*
Total	12	3		950·25		

TABLE 39.

Production from sampling Shaft No. 18.

Lithology of Sample : Green shale and sandstone.

Weight of sample—25 tons.

Serial No.	Weight in *Rattis.*	Estimated rate per *Ratti.*	Approximate value.	Quality.	Description (based on local terminology).
NO DIAMOND RECOVERED					

APPENDIX E—*concld.*

TABLE 40.

Production from a sample from Balahkadan.

Lithology of sample : Hard and compact "agglomeratic tuff".

Weight of sample—40 tons.

Serial No.	Weight in *Rattis*.	Estimated rate per *Ratti*.	Approximate value.	Quality.	Description (based on local terminology).
	Ra. An.	Rs.	Rs.		
1.	0 11	130·00	89·37	Cuttable gem	*Ujjwal, Chapto, Dhumrandar.*
2.	0 10	180·00	112·50	Cuttable gem	*Ujjwal, Chapto, Rukh, Lambo, Ashtang, Dhumrandar.*
3.	0 6	50·00	18·75	Industrial	*Mailepani, Chapto, Lambo, Garhan, Jiramdar, Samuro.*
4.	0 11	40·00	27·50	Industrial	*Mattho, Chapto, Lambo, Ashtang, Chinte, Dhumran, Vingramdar.*
5.	2 11	40·00	107·50	Industrial	*Mattho, Chapto, Lamberukh, Ashtang, Garhan, Chintan, Vingramdar.*
6.	1 8	30·00	45·00	Industrial	*Mattho, Chapto, Garhan, Dhumrandar.*
7.	0 11	60·00	41·25	Industrial	*Mailepani, Chapto, Lambo, Patak, Chintandar.*
8.	0 10	30·00	18·75	Industrial	*Mattho, Chapterukh, Gol, Garhandar.*
9.	0 9	30·00	16·88	Industrial	*Mattho, Chapto, Lambo, Samuro, Garhan, Chintandar.*
10.	2 7	35·00	85·31	Industrial	*Mattho, Chapto, Lambo, Garhan, Chintan, Dhumrandar.*
Total	10 14		562·81		

REFERENCES

ANON, 1956. Sampling Diamond Mines. *Mining Mag.*, Vol. 94 pp. 272-274.

JHINGRAN, A G. and PURI, S. N., 1956. A New Find of Agglomeratic Tuff in Bundelkhand Granite Area in Chhatarpur District, V. P. *Proc. 43rd Indian Sc. Cong.*, Pt. 3, p. 169.

MATHUR, S. M., 1953.—Diamond Mining and Recovery at the Majhgawan Mine in Panna, Vindhya Pradesh. *Indian Minerals*, Vol. 7, pp. 34-42.

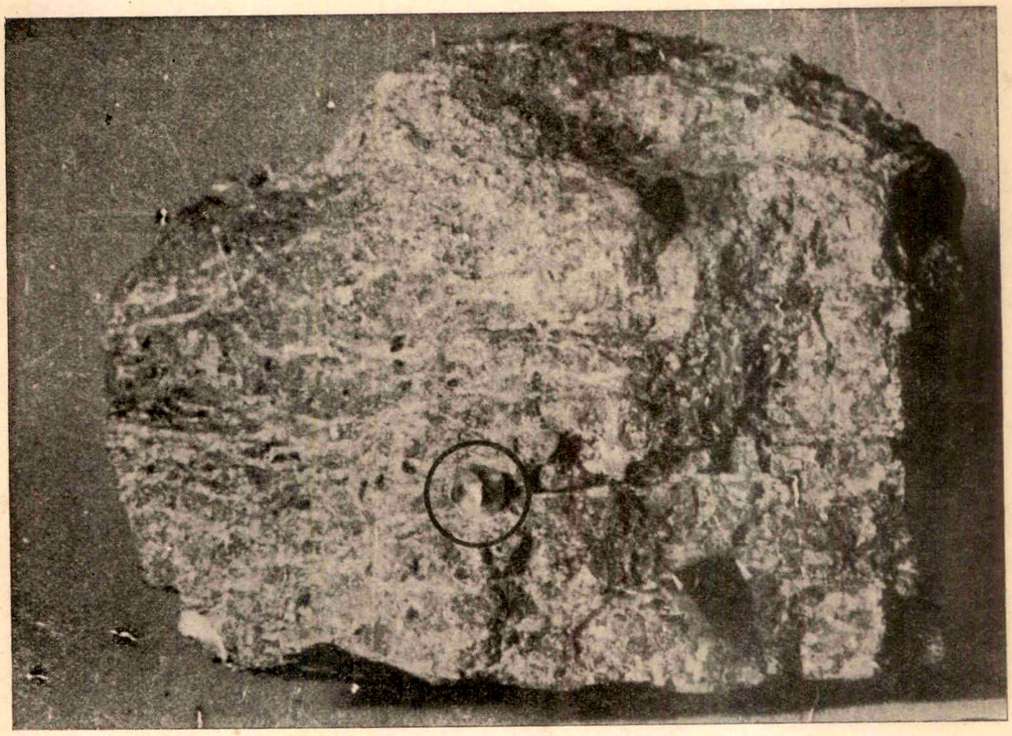
————, 1961.—Geology of the Panna Diamond Deposits. *Rec. Geol. Surv. Ind.*, Vol. 87, pp. 135-166.

SINOR, K. P., 1930.—The Diamond Mines of Panna State in Central India. Times of India Press, Bombay, p. 189.

VREDENBURG, E., 1906.—Geology of the State of Panna, Principally with Reference to the Diamond-bearing Deposits. *Rec. Geol. Surv. Ind.*, Vol. 33, pp. 261-314.

WAGNER, P. A., 1914.—The Diamond Fields of Southern Africa. The Transvaal Leader, Johannesburg, p. 347.

MGIPC—S5—15 GSI/60—24-10-62—1230.



A 3-CARAT DIAMOND (CIRCLED) IN THE "AGGLOMERATIC TUFF" FROM BALA KHADAN PIT, MAJHGAWAN MINE.

Photo : S. M. Mathur.

G. S. I., Calcutta.

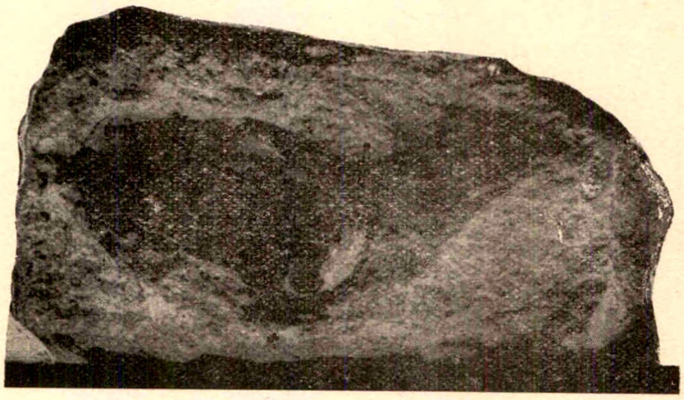


Fig. 1. INCLUSION OF HEMATITE PEBBLE IN "AGGLOMERATIC TUFF".

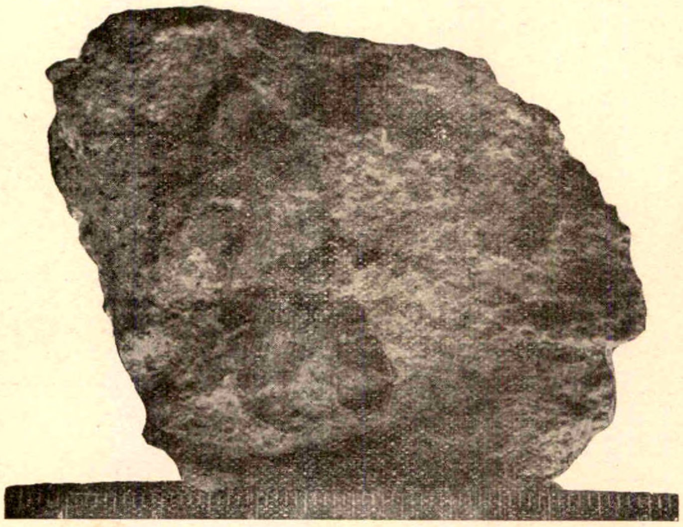


Fig. 2. COGNATE INCLUSION OF SERPENTINOUS ROCK IN "AGGLOMERATIC TUFF".

Photos : S. M. Mathur. *G. S. I., Calcutta*

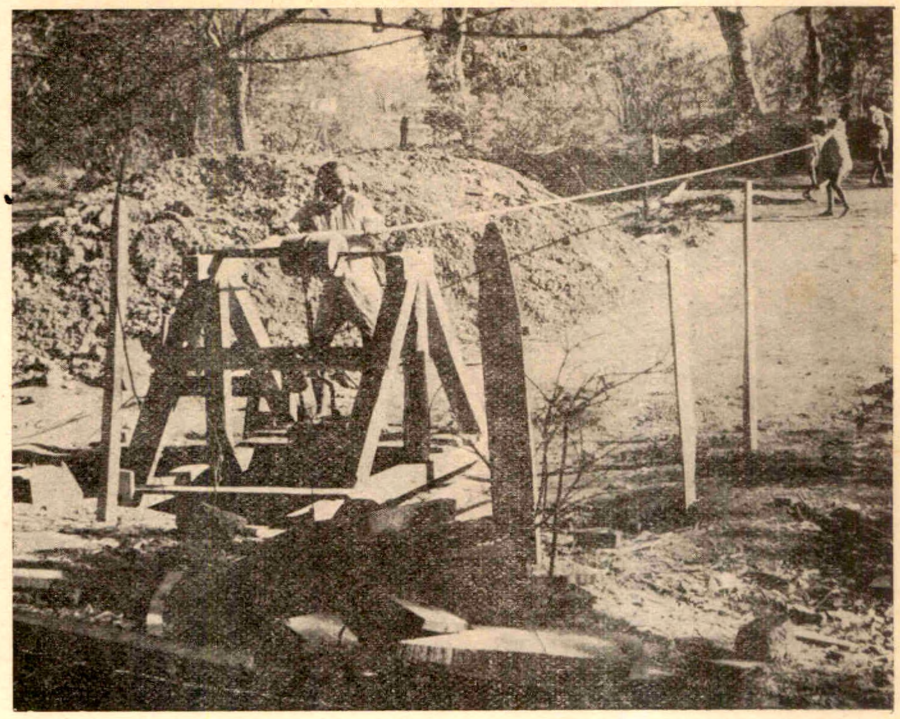


Fig. 1. VIEW OF A SHAFT ENTRANCE. IN THE ABSENCE OF A MECHANICAL GEAR HAULAGE IS DONE BY MANUAL LABOUR.

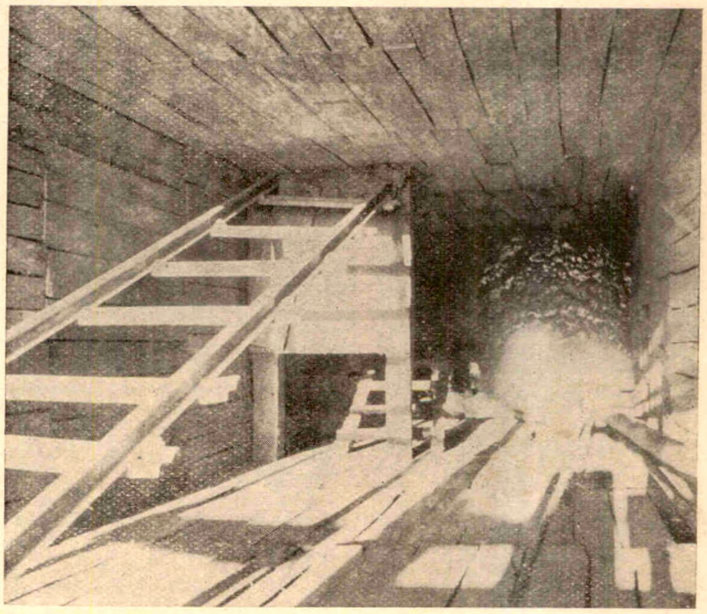


Fig. 2. INSIDE VIEW OF A SHAFT SHOWING TIMBER LINING AND LADDER WAY.

Photos : S. M. Mathur. *G. S. I., Calcutta*

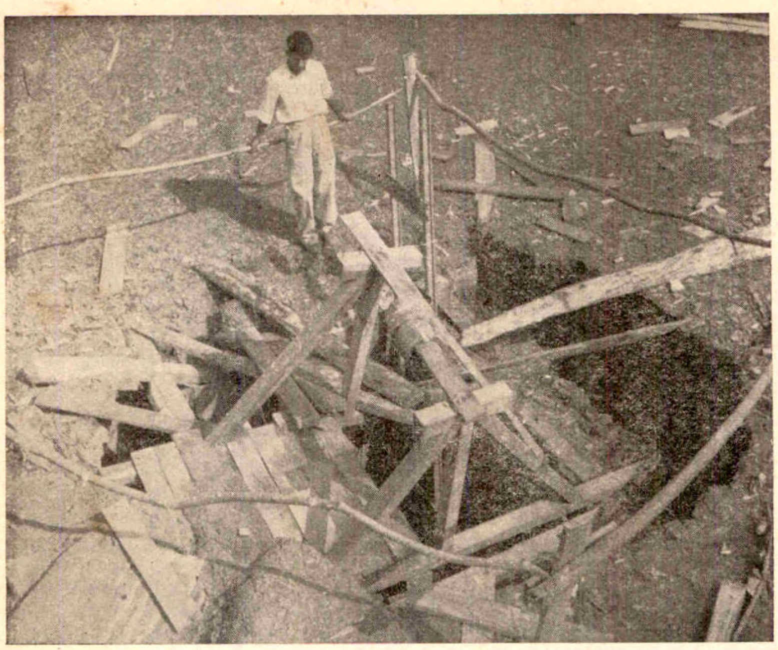


Fig. 1. HEAD FRAME OF A SHAFT IN REFILLED GROUND, WHICH COLLAPSED AT THE ONSET OF RAINS.

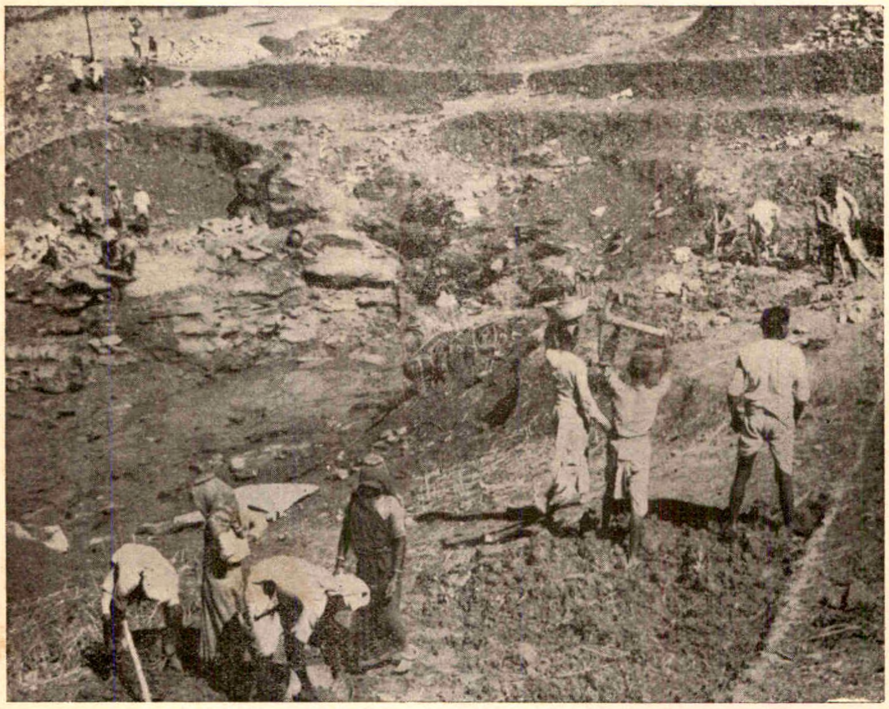


FIG. 2. A GENERAL VIEW OF BALAKHADAN WHICH IS THE ONLY WORKING QUARRY.

Photos : S. M. Mathur. *G. S. I., Calcutta.*

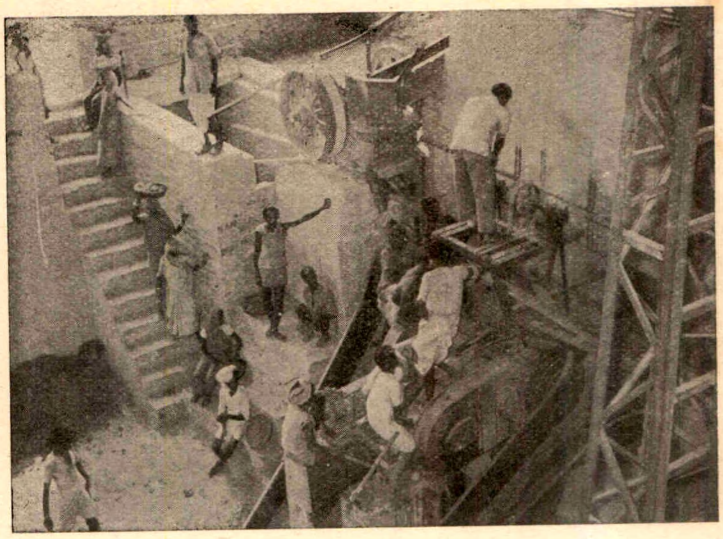


Fig 1. JAW BREAKER (TOP) AND ROLL CRUSHER (BOTTOM).

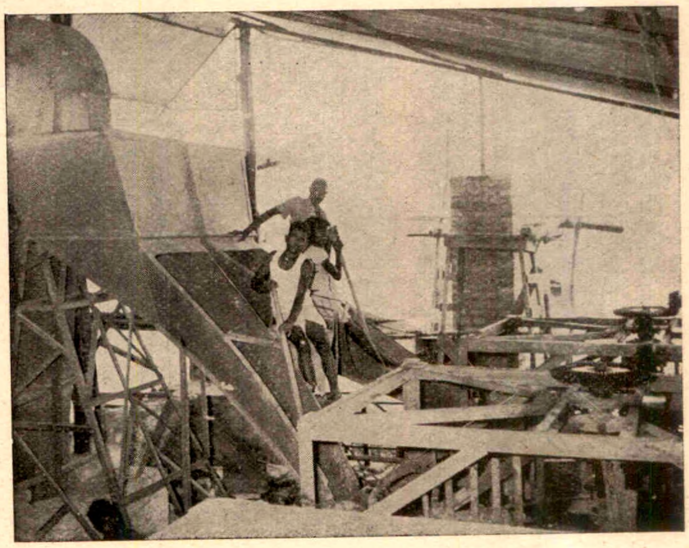
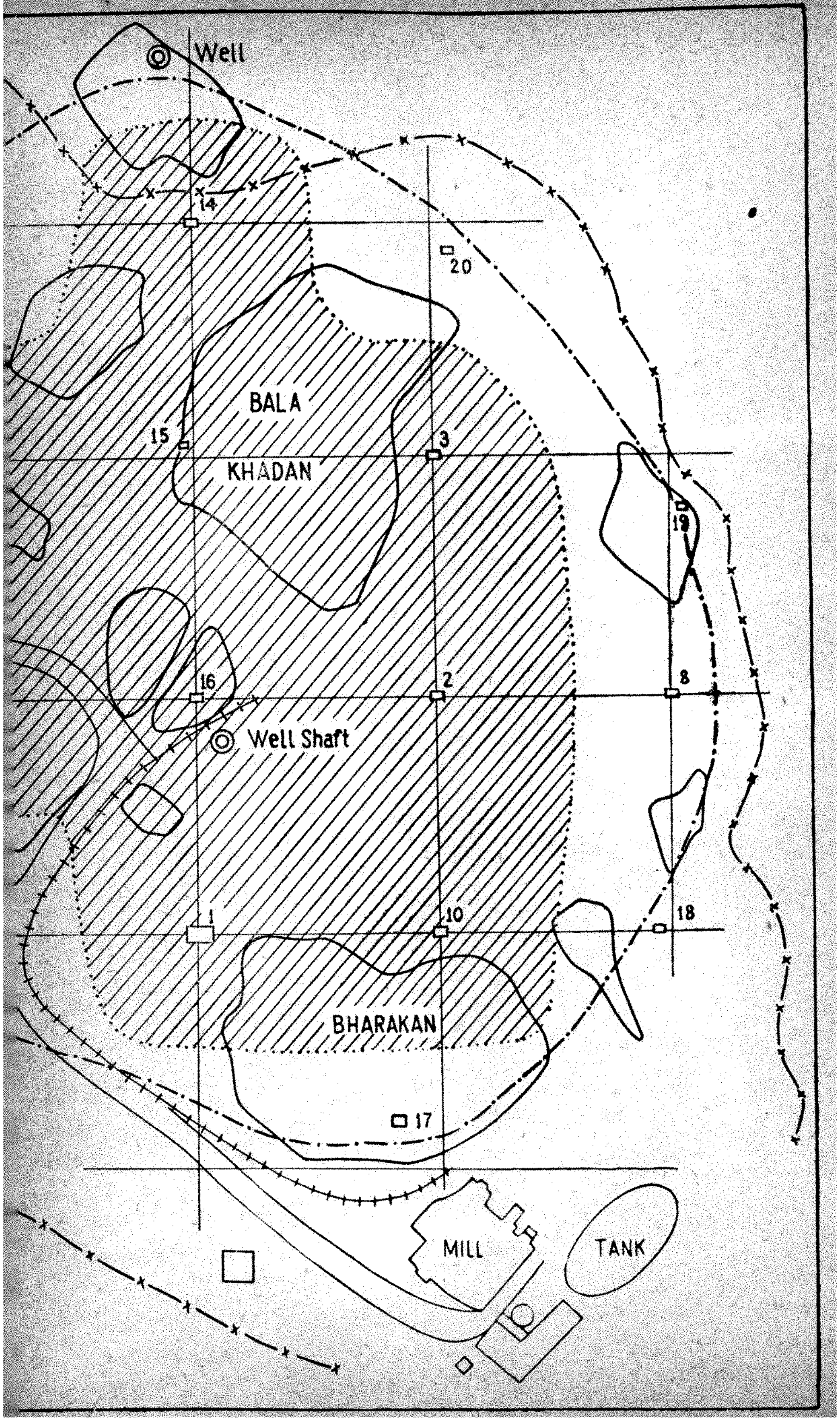
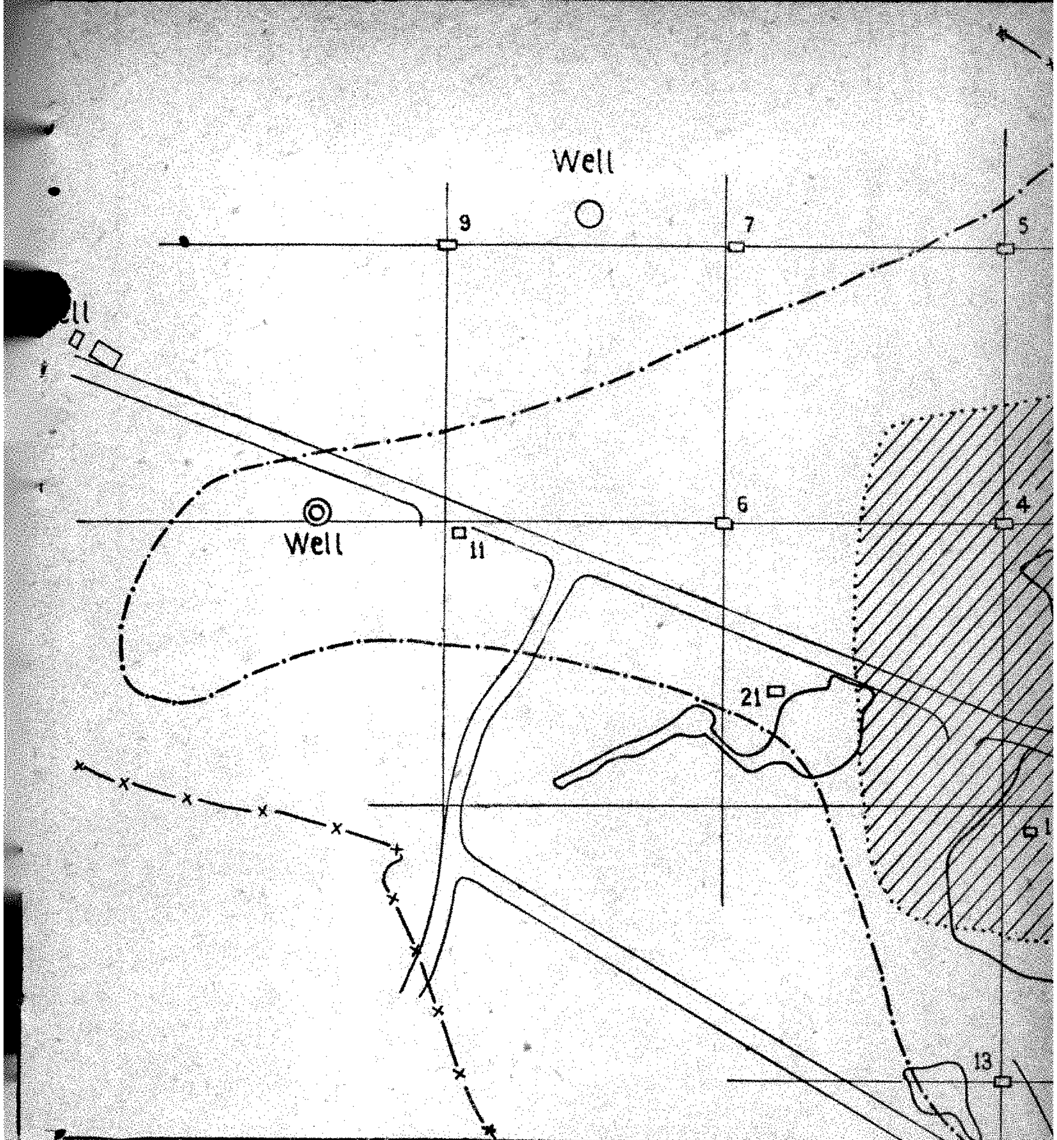


Fig. 2. THE HOPPER AT TOP LEFT. THE ORE IS BEING PUSHED DOWN INTO THE WASHING PAN.

Photos : S. M. Mathur.

G. S. I. Calcutta


Well
14
20
BALA
KHADAN
15
3
19
16
2
8
Well Shaft
1
10
18
BHARAKAN
17
MILL
TANK



PLAN OF THE MAJHGAWAN DIAMOND MINE SHOWING SCHEME OF SAMPLING

SCALE

FEET 150 120 90 60 30 0 150 300 450 FEET
Metres 25 0 25 50 75 100 125 Metres

BY S. M. MATHUR & H. N. SINGH, GEOLOGICAL SURVEY OF INDIA
Topographical Survey by S. C. Ghosh, G.S.I.

INDEX

Approximate limit of Pipe ------------------
Area of Influence of Agglomeratic Tuff Samples --▨
Sampling Shafts with Number ------------ □1
Existing Quarries ------------------

BULLETIN

OF THE

Geological, Mining & Metallurgical Society of India

NO. 25 MARCH, 1962

STRATIGRAPHY OF THE MAHADEO, LANGPAR, CHERRA AND TURA FORMATIONS, ASSAM, INDIA*

(With four figures and thirteen plates)

By

BUDDHADEB BISWAS[1]

ABSTRACT

The stratigraphic status of the Mahadeo, Langpar, Cherra and Tura Formations is discussed in the light of systematised codes of Stratigraphic Nomenclature. Reasons are forwarded for regarding these sedimentary sequences as rock units as distinct from time-stratigraphic (rock) units. Special emphasis is directed to the discussion of the type occurrences of these and associated formations. Emendations of the formations, based on rock stratigraphic evidences (and on pertinent paleontologic evidences), where appropriate, are suggested. Significant microfossils, including many new genera and species of fossil sporepollen, from these formations are described and illustrated.

INTRODUCTION

It is well known that the field study of sedimentary stratigraphic units involves an examination of the structure, succession, lithologic correlation and distribution of mappable rock units. Paleontological studies on the other hand aim at a more detailed investigation of the depositional environments of the rocks, and of their faunal, floral and precise geological time correlation. In some instances the biostratigraphic and time units of the paleontologist happen to coincide with the rock units of the field geologist. But in many other instances the biostratigraphic and time units do not coincide with the rock units, and, therefore, varying degrees of divergence between these types of units are involved from one area to another.

---

* Read before the Society on 16.2.62.

[1] Standard-Vacuum Oil Company, Producing Operations, Calcutta, India.

The coincidence of many rock units, at least in certain basin positions, with the biostratigraphic and/or time units, often causes a confusion of concepts, and rock units and time-rock (time-stratigraphic) units are interchangeably used too commonly. Instances are numerous, where a stratigraphic unit is defined on its rock characteristics, and, subsequently it is extended on the basis of its established or inferred time relations for one area, to regions or to basin positions, where the original time attributes are modified or even completely lost. With a view to eliminate such stratigraphic confusions, advanced geologists and stratigraphers from many countries of the world have tried to define the various kinds of stratigraphic units, their nature and their status. The American Commission of Stratigraphic Nomenclature (1961) in particular has codified the systematics of stratigraphic breakdown. The classes of stratigraphic units recognised are: (i) rock units, (ii) bio-stratigraphic (faunal/floral) units, (iii) time (geochronologic) units, (iv) time-stratigraphic (chronostratigraphic) units. The principal ranks of the rock, time, and time-stratigraphic units recognised by the American Commission are: (i) Group, Formation, Member, Bed, (ii) Era, Period, Epoch, Age, (iii) System, Series, Stage, respectively. Each of these schemes of classification is applied, independently of the others, to the same stratigraphic succession, in order to serve its respective purpose. All of these kinds of classification of the same stratigraphic unit, considered together, should not only enable a systematic description of the stratigraphic units but should indicate their geologic history with a reasonable degree of accuracy.

A confusion between rock units and time units has resulted in a considerable complexity in the stratigraphy of some of the Upper Cretaceous-Lower Eocene sedimentary rock successions of the Garo, Khasi and Jaintia Hills of the Shillong foreland shelf. An attempt has been made in this paper to resolve some of these complexities in course of reviewing the stratigraphic status of four controversial stratigraphic units of the South Shillong Front region of Assam, by a strict adherence to the systematic codes of Stratigraphic Nomenclature worked out by the American Commission of Stratigraphic Nomenclature, (figs. 1—4).

A REVIEW OF PREVIOUS WORK

Previous work on the geology of these rock successions from the Garo, Khasi and Jaintia Hills is by geologists and paleontologists of the Geological Survey of India, of the Burmah Oil Company, of the Universities and by individuals.

T. Oldham, first Director of the Geological Survey, did pioneering work on these Upper Cretaceous-Eocene rocks in 1851-1852, (1859). It is indeed an interesting account to read how he proved the occurrence of Eocene rocks with nummulitic fossils and suspected the occurrence also of Upper Cretaceous rocks in the Cherrapunji area (25° 17′ N : 91° 44′ E); that his fossil collections from these beds were lost in transit to the famous paleontologist Forbes; and how he finally confirmed his convictions from additional fossil collections from the same neighbourhood through his friends W. L. Atkinson and Dr. T. C. Jerdon (not geologists), casually visiting the area (1864).

H. B. Medlicott was the next geologist to attempt a systematic field geologic study of these successions from the central part of the Khasi Hills. He is the author of the rock units Mahadeo "band", Langpar "band", Cherra "band" and "Nummulitic Series" (1869). His fossil collections from the Mahadeo Formation and also from the Sylhet Limestone Formation were reported on by Stoliczka (1869) and described by Spengler (1923). Medlicott's Mahadeo "band" and Langpar "band" are essentially valid as mappable rock units even at the present day. It is remarkable that he included in his "Nummulitic Series" from the Therria Ghat section (25° 11′ N : 91° 46′ E) four beds of limestones and three clastic interbeds; that he noted the disappearance of the Cherra "band" downdip from the Cherrapunji Plateau; and that he considered the coal-bearing sandstones as well as the conformably underlying limestones of Cherrapunji area as belonging to his "Nummulitic Series". It may be mentioned that much of the confusion pertaining to the Cherra Formation, that has subsequently crept into literature, is largely due to departure from the original definition of this rock unit subsequently introduced by later workers. However, Medlicott's own inferred correlation of the coal-bearing sandstones of the Garo Hiils, and of the northern part of the Khasi Hills, north of latitude 25° 20′ N approximately, with the type occurrence of the Cherra "band" has been proved to be erroneous as a result of more detailed studies by Fox and Ghosh.

La Touche observed that the coal of Cherrapunji occurs 10 feet above a 75-80 feet thick nummulitic limestone sequence (1889), the whole succession being conformable. A comparable relationship for the coal of the Lakadong coalfield and underlying nummulitic limestones was recorded by La Touche (1890). It was not known then that these nummulitic limestone beds are the same as the bottommost limestone beds of the "Nummulitic Series" of Therria Ghat of Medlicott (1869).

In course of field studies on the western part of the Khasi Hills, Palmer (1923) followed the same scheme of stratigraphic classification of these sediments as suggested by Medlicott. In his preliminary studies Palmer, however, did not distinguish between the "Bottom conglomerate", "Mahadeo Beds", "Langpar Band" and "Cherra sandstone" for purposes of field mapping. Instead, he treated all of these rock units as Cretaceous.

For reasons difficult to understand, Holland attributed the macrofauna occurring in the Mahadeo Formation, to the "Cherra sandstone" in his compendium "Indian Geological Terminology", (1926).

Das Gupta described "Lower-Middle Khirthar" foraminifera from the Sylhet Limestone Formation of the Cherrapunji area and discovered calcareous algae from these rocks (1926). These limestones have since been found to be the basal member of the Sylhet Limestone Formation and of Paleocene age. Das Gupta described Upper Senonian macrofauna from the Mahadeo Formation, (1929).

Evans pointed out that the succession "Mahadeo bed", "Langpar band" and "Cherra sandstone" is of local value in parts of the Khasi Hills (1932). Further, Evans regarded the coal-bearing sandstones, underlying the Sylhet Limestone Formation, of the Mikir Hills, to be Eocene, and as such to be stratigraphically unrelated to the Cretaceous succession of the Cherrapunji Plateau. However, Evans was unanimous with the Geological Survey in considering the infra-Nummulitic coal-bearing sandstones of the Garo Hills as Cretaceous. Besides, the coal-bearing sandstones of Cherrapunji and of Lakadong (25° 10′ N.: 92° 17′ E) areas, regarded as the "Kopili stage" by Evans, have later been proved by Nagappa, and by Wilson and Metre, to really constitute the lower part (basal member) of the Sylhet Limestone Formation.

Subsequent work on the Garo, Khasi and Jaintia Hills was by the Geological Survey during 1934-1938. Fox himself worked on the Garo Hills and he supervised the work done in the Khasi Hills, mainly by A. M. N. Ghosh. The Cretaceous and Eocene succession of the Jaintia Hills was studied by P. N. Mukherjee in the later stages. Fox suggested that the infra-Nummulitic coal-bearing sandstones of the Garo Hills are of an Eocene age and are basically unrelated to the "Cherra sandstones", (1936a, 1936b), and proposed the designation "Tura sandstone (Cherra) stage" for this succession (1937). Later, A. M. N. Ghosh suggested that the "Tura Standstone Stage" is a lateral facies development of the middle and/or lower part of the "Sylhet Limestones", (1954). A. M. N. Ghosh (and later Fox) preferred to include the upper three nummulitic limestone "bands", and two clastic interbeds of the Therria Ghat succession, within the "Sylhet Limestones". Further, these authors not only extended the vertical definition of the "Cherra Sandstone Stage" by including in it the lowest clastic interbed (often with coal) and the basal limestones of the Sylhet Limestone Formation (1936, 1937, 1938, 1939), but Ghosh extended the downdip limit of this stratigraphic unit in designating the bottomost limestones and overlying sandstones of the Therria Ghat section as the "Cherra stage" (1940, p. 8). Ghosh (and Fox) established that the Cretaceous stratigraphic units of the Khasi Hills seldom occur north of latitude 25° 20′ N, and that the clastic beds presumably of Eocene age, outcropping in the more northerly areas, have an unquestionable overlapping relationship with the underlying Cretaceous sequences. Doubtless they followed Medlicott in considering these northerly clastic developments as the "Cherra sandstone". However, in the opinion of the present writer, the conglomerate-sandstone successions of areas, to the north of and depositionally updip from the northern most occurrence of the limestones of the Sylhet Limestone Formation, constitute a separate (as yet undesignated) formation, rock stratigraphically unrelated to the Cherra Formation of the Cherrapunji Plateau.

Das demonstrated that the "Cherra sandstone" of the type area, distinctly and persistently, underlies the "Nummulitics" (1940). But his idea of a basinwide unconformity between the Cherra Formation and the Sylhet Limestone Formation has been found to be untenable in the light of additional data.

A. K. Ghosh illustrated a pollen of the "Podocarpinae" from a carbonaceous shale of Tertiary age (Eocene) from "Laitryngow" and reported the occurrence of rich pollen in a good state of preservation in this material (1941).

Sen published on the fossil sporepollen of Laitryngew (25° 9′ N : 91° 45′ E according to Sen, 25° 20′ N : 91° 44′ E according to A. M. N. Ghosh) coal, considered to belong to the "Cherra sandstone", and inferred that the fossil sporepollen evidence is compatible with an Eocene field correlation (1948). It is difficult to be sure if the fossil sporepollen evidence presented in this study is conclusive of an Eocene correlation of the coal, and assuming it is, the question remains whether this coal is coeval with, or really a part of the Sylhet Limestone Formation, or of the Cherra Formation. It is likely that several coal-bearing sedimentary beds were deposited in the far north areas of the Khasi Hills, corresponding to the phases of limestone deposition of the Sylhet Limestone Formation of the southerly sections, and that some of the coaly horizons that might have escaped erosion are represented in areas north of Cherrapunji.

Rao described Lower-Middle Eocene calcareous algae of the subfamilies Melobesieae and Corallineae from limestones underlying the "Cherra Sandstone" of Nongstein (25° 17′ N : 91° 39′ E) and Langrin Cliff (vicinity 25° 11′ N : 91° 7′ E) etc., (1943, 1947). There is very little doubt that the algae described by Rao are mostly from the basal to lower part of the Sylhet Limestone Formation.

Nagappa proved the Paleocene age of the "lower part of the Sylhet Limestone" of the Cherrapunji area from a study of Das Gupta's collection (1951a). These limestone beds of the Cherrapunji area constitute the basal member of the Sylhet Limestone Formation in the Khasi-Jaintia Block, as far as can be judged by the present writer. Nagappa referred to the occurrence of *Miscellanea* in the "lower parts of the Sylhet Limestone" from other areas of the Khasi-Jaintia Hills; he further mentioned the occurrence of *Pellatispira cf. orbitoidea* (Provale) in the "upper beds of the Sylhet Limestone", (1951b). It has since been found by the writer that, in the region between the Khasimara River section (25° 12′ N : 91° 30′ E) and Um Sohryngkew River Section (25° 11′ N : 91° 46′ E), the basal part of the Sylhet Limestone Formation is characterised by the *Miscellanea spp.* Assemblage-Zone and its top by the *Pellatispira spp.* Assemblage-Zone, although in the Jaintia Hills the section corresponding to the uppermost member of the type occurrence of the Sylhet Limestone Formation often has a tendency to develop a dominantly calcareous shaly facies corresponding to the lower part of the type Kopili Formation.

In a composite section for the Khasi-Jaintia Hills ("southern and eastern parts of the Shillong Plateau") Wilson and Metre included the three upper limestone beds and interbedded clastics within the "Sylhet Limestone" both on "lithological and paleontological evidence", (1953). They designated these limestone beds and the clastic interbeds of the Jaintia Hills in descending order as: (a) "Prang Limestone" (Middle Eocene), (b) "Narpuh Sandstone", and "Umlatdoh Limestone" (Lower Eocene), (c) "Lakadong Sandstone" and "Lakadong Limestone" (Paleocene). Wilson and Metre composited the third clastic interbed (counting from top), and the fourth limestone beds (counting from top) of the Therria Ghat section, with the above mentioned developments of the Jaintia Hills, as if the entire succession could be traced all over the southern part of the "Central Assam Range". They designated these lower sandstone and limestone beds of the Therria Ghat section, previously included by Medlicott in his "Nummulitic Series", as the "Upper Therria Substage" and "Lower Therria Substage" respectively of the "Tura Sandstone" of (lower) Paleocene age. The status of the Cherra Formation was not specifically discussed by these authors.

Nagappa in connection with description of *Eorupertia boninensis* and *Fabiania indica* from the "Prang Limestone" of the Um Sohrngkew, Hari, Prang and Lubha River sections followed the same breakdown of the "Sylhet Limestone" as outlined by Wilson and Metre (1953). However, he designated the immediately underlying sandstone beds and the limestone beds as the "Tura (Cherra) Beds" of "?Paleocene" age.

Further modifications in respect of the stratigraphic breakdown of the "Sylhet Limestone" and underlying successions have been introduced by Nagappa (1959). In this paper Nagappa proposed the "Prang Stage" for the "Prang Limestone" of Wilson and Metre (1953); he united the "Narpuh Sandstone" and "Umlatdoh Limestone" of Wilson and Metre into the "Narpuh Stage"; he included the "Lakadong Sandstone and Lakadong Limestone" of Wilson and Metre within his "Lakadong Stage"; he introduced the "Therria Stage" for the "Upper Therria Substage" and the "Lower Therria Substage". Nagappa subdivided the Cretaceous-Danian (Paleocene) sediments of "Central Assam Foot Hills" into the "Langpar stage" and "Mahadek stage". Although Nagappa mentioned that the stratigraphic classification of these stratigraphic units, as presented by him (1959, p. 163), is based on Wilson and Metre's account (1953, p. 120), considered in a formal stratigraphic sense, these two classifications are obviously different. In a later publication (1960) Nagappa considered the Langpar "stage" to be Lower Paleocene. Thus, according to Nagappa, there are three stages in the Paleocene of the South Shillong Front, namely, the "Langpar stage", the "Therria stage" and the "Lakadong stage".

A perusal of the foregoing account of the more important previous works on the subject should furnish an idea of the diverse terminological treatment to which the Upper Cretaceous-Eocene stratigraphic units of the Garo-Khasi-Jaintia Hills have been subjected. The present writer is disinclined to create legalistic quibbles over the terminological intricacies of these sediments. However, it is apparent that each of the terms used by previous workers in describing these stratigraphic units has a definite significance and bearing in the context of a systematic classification of these sedimentary rocks. It will also be apparent that a systematic stratigraphic breakdown, and an uniform nomenclatural treatment are fundamentally connected with a resolution of the age-old stratigraphic complexities associated in particular with the Cherra Formation, Tura Formation and Sylhet Limestone Formation. Therefore, it is necessary to discuss at length a few of the pertinent points bearing on this problem.

1. There are four limestone beds and three clastic interbeds, overlying the Langpar Formation, in the Therria Ghat area and in the immediately adjacent parts of the Khasi and Jaintia Hills. These beds constitute one mappable rock unit and may logically be regarded as a single formation. Medlicott termed this rock succession as the "Nummulitic Series". The designation "Nummulitic Series" is not appropriate because, (1) series is a time-stratigraphic unit (and not a rock stratigraphic one), (2) a mappable rock unit should not be attributed to any fossil occurring in it. Therefore, these four limestone beds and the associated clastic interbeds may conveniently be regarded to constitute the type Sylhet Limestone Formation. Such a designation not only takes into consideration the mappable rock characteristics of this succession but is also very close (as close as one could perhaps go) to the firmly established current usage of this stratigraphic unit. The fourth limestone bed (counting from top) of the Sylhet Limestone Formation may be (informally) regarded as the basal member of the Sylhet Limestone Formation. The third clastic interbed and third limestone bed (counting from top), the second clastic interbed and second limestone bed, the first clastic interbed and topmost limestone bed may be classified (informally) as the lower, middle and upper members respectively of the Sylhet Limestone Formation. The basal member of the Sylhet Limestone Formation has yielded abundant Paleocene larger foraminifera (including *Miscellanea miscella*) and calcareous algae from the Khasimara (25° 12′ N: 91° 31′ E), Umiam (25° 11′ N : 91° 39′ E) River sections as well as from the Cherrapunji (25° 17′ N : 91° 44′ E) and Lakadong (25° 10′ N : 92° 17′ E) areas, although fossils are of rare occurrence in the Therria Ghat occurrence of this member (apparently due to a recrystallised nature of the limestones). Therefore, the basal member of the type Sylhet Limestone Formation would appear to be synonymous with the lower parts of the "Therria stage" and "Lakadong stage". The outcrops of the lower member of the Sylhet Limestone Formation, like the basal member, are developed only in parts of the Khasi-Jaintia Hills, and this member is characterised by the occurrence of very shallow marine Lower Eocene fossils. Neither the lower (limestone) member of the Sylhet Limestone Formation, nor any of its other overlying members, occurs in the Cherrapunji Plateau. Whereas it is possible that the lower, middle and upper members of the Sylhet Lime-

stone Formation were never deposited in the Cherrapunji Plateau area, it is more likely, in view of the generally more extensive nature of the middle and upper Eocene marine transgressions, that these members (particularly the middle and upper members) were deposited in the Cherrapunji Plateau area and have subsequently been denuded away. The middle and upper members of the Sylhet Limestone Formation have a basinwide development and occur along the entire foreland shelf of the Shillong Plateau from the Garo to the Mikir Hills, and beyond. However, paleontological evidence is conclusive (occurrence of *Pellatispira spp.*) for inferring that the topmost part of the upper member of the Sylhet Limestone Formation of the Therria Ghat area is the time equivalent locally of the lower part of the Kopili Formation of the Jaintia Hills (because of a greater supply contemporaneously of clay grade clastics in the latter area).

2. The sandstone beds underlying the basal member of the Sylhet Limestone Formation and overlying the Langpar Formation are mappable locally in the Cherrapunji Plateau and thus constitute the Cherra Formation in the sense of original definition of this rock unit. Downdip from Cherrapunji the sandstones gradually shaleout, so much so that in the Therria Ghat section the Cherra Formation is unrepresented as such and seems to be proxied by a "stretched" Langpar Formation. The formation loses its mappability approximately four miles north of Cherrapunji, north of latitude 25° 20′ N. The sandstone beds, with interbedded coal seams, north of this parallel, have been treated in the previous literature as the "Cherra sandstone stage", but these rocks seem to constitute a separate formation unrelated to the Cherra Formation proper, and are probably an, as yet undesignated, updip clastic development corresponding to the Sylhet Limestone Formation of the more southerly areas.

3. The Tura Formation is essentially a mappable rock unit, developed locally in the Garo Hills. From available paleontological data it may be inferred that the Tura Formation largely represents a lateral facies development corresponding to the lower, and part of the middle member of the Sylhet Limestone Formation of the Khasi-Jaintia Hills. It is rock stratigraphically unrelated entirely to the Cherra Formation of the Cherrapunji Plateau and to the "Therria stage".

SCOPE OF THE PRESENT STUDY

The present study is based on an office investigation of the rock stratigraphy of numerous sections measured from the southern scarp sections of the Garo, Khasi and Jaintia Hills, Assam, by the field geologists of the

Standard-Vacuum Oil Co. The rock stratigraphic studies have been supplemented by an investigation of some of the plant and animal microscopic fossils characterising these formations. A review of all significant published work bearing on the stratigraphy of the formations has also been attempted.

The writer has tried to make a distinction between rock stratigraphic and time-stratigraphic units in an attempt to establish an objective classification of the stratigraphic units in question. As these stratigraphic units are basically mappable rock successions, a rock unit nomenclature is followed in suggesting their formal designation. In the rock stratigraphic nomenclature of these sediments, the designations that have priority have been followed, provided that such nomenclature is deemed stratigraphically valid.

Mapping of disconnected or of poorly accessible outcrops of rock units, such as, those exposed in the stream sections cutting through the Shillong Plateau, is associated with the problem of identifying the various beds with one another across areas of no exposure or of difficult access. The importance that paleontologic studies, specially a study of the marine as well as of freshwater microfossils, may assume in the correlation of strata in such instances, is emphasised. A correlation of the stratigraphic units of Assam with the classical European time-stratigraphic units, such as, "Danian" and "Senonian" have been indicated, emphasising thereby the biostratigraphic correlation that exists (not necessarily implying an absolutely identical time correlation).

The stratigraphic value of this discussion is limited to some extent inasmuch as material from the type sections of all the formations is not available.

SYSTEMATIC STRATIGRAPHY

MAHADEO FORMATION

Author: Medlicott, H. B., 1869, p. 178.

Type Section : The formation owes its name to outcrops in the vicinity of Mahadeo village (25° 13′ N : 91° 45′ E), in a stream under Laisophlang village.

Typical Sections: There are no formally designated typical sections. However, in view of the known variations in a north-south direction as well as along the east-west strike trend (towards the edges of the then Khasi-Jaintia depositional trough), a designation of several typical sections will undoubtedly enhance the understanding of the nature and characteristics of the spatial distribution of the formation.

Lithology: By definition, strongly glauconitic sandstones with considerable disseminated carbonate of lime constitute the formation in the type area, although thick beds of "earthy matter" occur in other areas.

"Great bottom sandstones" and "basal conglomerates", underlying the glauconitic sandstones, apparently are near-littoral and shoreline developments associated with the glauconitic upper member of the formation, and these beds may be conveniently included as the middle and lower members respectively of the Mahadeo Formation.

Lower Contact: The Mahadeo Formation rests unconformably on the Sylhet Trap Formation in the type area, and in areas to the south of the type area. It lies with an erosional unconformity on the Precambrian basement complexes in its extreme updip occurrences to the north.

Upper Contact: Mahadeo Formation is apparently the topmost rock unit exposed in the immediate vicinity of the Mahadeo village, but it is conformably overlain by the Langpar Formation in areas further south and further north of the Mahadeo village.

Structures: In its northerly occurrences the Mahadeo Formation is nearly horizontal. It has low southerly regional dips in the type area. The Mahadeo terrace is associated with a fault dislocation with a southerly throw. The fault had apparently been initiated in the Upper Cretaceous times. Steeper dips characterise the outcrops of the Mahadeo Formation involved in the monoclinal flexure south of the Mahadeo terrace and dips of the order of 50° have been recorded from the Therria Ghat area. The formation has more gentle dips of the order of 16° near Dauki (25° 11′ N: 92° 02′ E).

Thickness and areal distribution: Measured sections of the formation for the type area are not available. The formation appears to be 500 feet thick in the type section.

The northern limit of development of the Mahadeo Formation approximately coincides with 25° 20′ N parallel. The southern limit of outcrops of the formation is marked generally by 25° 11′ N parallel in the Um Sohryngkew River section. The width of the outcrop of the Mahadeo Formation is of the order of 10 miles.

Jadukata (Kynshiang) River to the west (91° 10′ E approximately) and Dauki (25° 11′ N : 92° 02′ E) to the east mark the lateral extension of the outcrops of unquestionable Mahadeo Formation, a stretch of nearly 60 miles.

Geologists are unanimous about an increase in the thickness of the formation in the southern scarp sections (1000 feet generally) as compared to some 500-600 feet of section in the type occurrences. The formation thins rapidly to the north of the type area, disappearing altogether within some 4 miles north of Cherrapunji (25° 17′ N : 91° 44′ E). The north-south variation of the thickness of the formation is associated with an increased development of an argillaceous deeper shelf facies south of the type occurrence, and of a dominantly pebbly shoreline facies north of Cherrapunji. It is possible that the basal beds of the Langpar Formation of the southern scarp sections are the time equivalents of the topmost beds of the Mahadeo Formation of the more northerly areas.

It is interesting to note that the thickest development of the Mahadeo Formation, in between the Umiam (Boga Pani) River (25° 12′ N : 91° 39′ E) and Um Sohryngkew River (25° 11′ N : 91° 46′ E), coincides with the thickest development of the Sylhet Trap Formation. All available evidences indicate that this and immediately adjacent portions of the Khasi-Jaintia Block formed a more conspicuously subsiding block compared to the adjacent shelf areas in the Upper Cretaceous times.

Fossils, age, paleoecology : Microfaunas from the type section of the Mahadeo Formation are not described to date. The smaller foraminiferal faunas from the "Mahadek stage" of the Therria Ghat section recorded by Nagappa appear to belong to the Langpar Formation on rock stratigraphic considerations. Photomicrograph of a thin section of a fragment of an orbitoid from the *Ostrea (Alectryonia) ungulata* zone of this formation from the Dauki area is illustrated in this paper, pl. 1. Undoubtedly better preserved microfaunas occurring in this formation will be found in future on a specific search. Nagappa has illustrated *Siderolites calcitropoides* from the Mahadeo Formation of the Cherrapunji area (1959).

Macrofaunas from this formation have been described by Stoliczka (1869), Spengler (1923) and Das Gupta (1929) from the vicinity of Mahadeo, Therria Ghat, Mamluh (25° 15′ N : 91° 42′ E), Sokha (25° 13′ N : 92° 02′ E), Jowai (25° 26′ N : 92° 12′ E), Nonjuri (25° 11′ N : 91° 38′ E), Tangmang (25° 14′ N : 91° 38′ E), Wahmlein near Tangmang, Pornai (25° 16′ N : 91° 56′ E) and Nangtalang (25° 12′ N : 92° 4′ E).

The upper and lower age limits of the type occurrence of the Mahadeo Formation is controversial to some extent. Stoliczka claimed a Cenomanian "age" of the macrofauna from the middle part of the type section of the formation. But Spengler indicated an Upper Senonian macrofaunal correlation of the outcrops of the Mahadeo Formation from the various parts of the Khasi-Jaintia Hills, including that of the type section. Spengler, however, pointed out that macrofaunal collections from the different areas and also from different stratigraphic units of the Khasi-Jaintia Hills were mixed up. A systematic collection of fossils from the various beds of the Mahadeo Formation, essential for a reliable resolution of the upper and lower age limits of the formation, seems to never have been attempted.

Das Gupta (1929) recorded the occurrence of the Upper Senonian echinoid *Pyrina ataxensis* from the type occurrence of the Mahadeo Formation. *P. ataxensis* also occurs in the "*Hemipneustes* Beds" of Baluchistan. A. M. N. Ghosh noted the occurrence of *Stigmatopygus* sp. in the type section of the formation.

Some of the well known Campanian-Maestrichtian forms, known presumably from the upper part of the Mahadeo Formation of Therria Ghat and other areas are *Stigmatopygus elatus, Gryphea vesicularis, Ostrea (Alectryonia) ungulata, Baculites vagina.* The claimed close similarity of the known macrofauna of the Mahadeo Formation with those of the "Ariyalur Stage" seems to be generally well founded.

Specific studies on the depositional environment of the macrofaunas and microfaunas of this formation are lacking. From an examination of the petrographic and faunal characteristics of the formation an open marine sublittoral-neritic depositional environment, with a moderately steeply dipping bottom of the deposition basin (towards south), is suggested.

Spengler noted that the macrofaunas from the Mahadeo Formation have a strong Indo-Pacific aspect and present a sharp contrast with contemporaneous Mediterranean-Tethyan assemblages. It may be pointed out that the principal difference between most of the Upper Cretaceous Mediterranean-Tethyan and Indo-Pacific faunal assemlages is believed to be fundamentally related to the ecologic factors rather than to the zoogeographic ones. For instance, the characteristic association of Rudistids and foraminifera of the families *Peneroplidae* and *Orbitoididae* in the Tethyan assemblages indicate a prevalence of reefal depositional conditions. It is suggested that whereas there was an effective marine intercommunication between the Mediterranean, Tethyan and Indo-Pacific provinces in the Upper Cretaceous times, instances of reefal deposition are rare in the areas of outcrops of the Mahadeo Formation.

Stratigraphic Status: Mahadeo Formation has variously been described in previous literature as the "Mahadeo band", "Mahadeo bed" and "Mahadek stage".

Since this stratigraphic unit is a mappable succession of beds, it may be regarded as the Mahadeo Formation. (Spelling originally indicated in the publications of the Geological Survey is Mahadeo, and is the one maintained in this paper; in subsequent editions of toposheets Survey of India has used the spelling "Mahadek").

According to its author Medlicott, the Mahadeo "band" applies only to the glauctonitic sandstone beds, and he uses the terms "great bottom sandstones" and "basal conglomerates" in designating the underlying and invariably associated rock sequences. It is here proposed that the original connotation of this unit be revised to include under the Mahadeo Formation the following informal members, so far as a mappable relationship among these members themselves and with the overlying as well as overlapping Langpar Formation can be recognized in the field:

(i) upper member for the glauconitic sandstones underlying the Langpar Formation
(ii) middle member for the non-glauconitic sandstones underlying the upper member
(iii) lower member for the basal pebble beds.

Formal subdivisions, if any, of the Mahadeo Formation should be designated, if and where appropriate, on the basis of additional field studies.

LANGPAR FORMATION

Author: Medlicott, H. B., p. 170 and 179, 1869.

Type Section: The formation is named after the Langpar spur, south of Mawsmai (25° 14′ N : 91° 44′ E), alternatively spelt Maosmai, south of the Cherrapunji Plateau in the Khasi Hills.

Typical Sections: No typical sections have been formally designated. Medlicott expressed his preference for the section at the head of the Nongpriong Valley (25° 17′ N : 91° 45′ E), east of Cherrapunji as one of the typical sections of the formation. Several other typical sections from the Khasi Hills may conveniently be designated in order to indicate the nature of short distance facies variation, known to characterise this and associated formations, in a lateral direction as well as along the direction of dip of the formation.

Lithology: Medlicott described the type Langpar Formation as fine-grained sandy limestones. A detailed description of the lithology of the Langpar Formation in the type area is not available in published literature.

According to Medlicott, the formation in many other places near the type area consists of very fine pale colored sandstones and "earthy beds", generally coated with a dark brown or black patina of iron oxide, but associated everywhere with "a calcareous ingredient in a strangely capricious manner." The formation consists of calcareous shales, with thin limestone interbeds, in the Therria Ghat Section.

Lower contact: The Langpar Formation rests conformably on the Mahadeo Formation, and the passage between these two formations seems to be completely gradational in the southern scarp sections.

Upper Contact: The Langpar Formation is conformably overlain by the Cherra Formation (as originally defined by Medlicott) in the type area. In the southern scarp sections the basal member of the Sylhet Limestone Formation conformably overlies the Langpar Formation. Since the Cherra Formation pinches out south of the Cherrapunji Plateau so as to be unrepresented as such in the Therria Ghat and adjacent scarp sections (as noticed by Medlicott, 1869, and Fox, 1936 a), it may be presumed that the upper part of,the Langpar Formation in the southernmost areas of outcrops represents a contemporaneous downdip shaly development corresponding to the Cherra Formation of the more notherly areas.

Structure: The formation has low southerly dips in the Cherrapunji Plateau; south of Mawsmai it has steeper dips and the dip of the beds in the southern scarp section is of the order of 50° to the south.

Thickness and areal distribution: Thickness of the Langpar Formation in the type area is of the order of 200 feet. The formation is 300-400 feet thick in the southern scarp sections. It thins to the north. The northernmost limit of the Langpar Formation is about a mile further north of that of the Mahadeo Formation. The formation thins towards the Khasimara River (25° 12′ N : 91° 30′ E) and seems to wedgeout completely in between the Khasimara and Mukhai (25° 13′ N : 91° 22′ E) Rivers.

The Langpar formation thins to the east of the Um Sohryngkew River and is not represented in Dauki.

Fossils, age, paleoecology: Abundant smaller foraminiferal faunas from the Therria Ghat occurrence of the formation include: *Frankeina taylorensis, Marssonella oxycona, Nodosaria affinis, Palmula primitiva, Frondicularia verneuiliana, Ramulina cf. arkadelphiana, R. cf. navarrona, Pseudouvigerina plummerae, Rectogumbelina cretacea, Bulimina cf. kickapooensis, Bolivina incrassata* and *Globigerina cretacea.* Associated are numerous other species of smaller foraminifera. It may be mentioned that the rock succession at Therria Ghat, from which Nagappa (1959) has described forms, such as, *Globotruncana stuarti, Gumbelina plummerae, Pseudotextularia, Ventilabrella, Orbitoides, Siderolites calcitropoides,* seems to be rock stratigraphically a part of the Langpar Formation, rather than that of the "Mahadek stage". Among the numerous smaller foraminiferas from the outcrops of the Langpar Formation in between the Mukhai River and Mawpen (25° 13′ 45″ N : 91° 26′ 30″ E) are: *Marssonella oxycona, Frankeina* sp., *Nodosaria affinis, Frondicularia verneuiliana, F. arkadelphiana, Gumbelina cf. moremani, Pseudouvigerina plummerae, Anomalina rubiginosa, "Marginulina sp. A* from the Corsicana marl" etc.

From the topmost part of this formation, outcropping near Therria Ghat, Nagappa has described *Globigerina pseudobulloides* and *Globigerina triloculinoides,* (1959). Occurrence of the following acid insoluble microfossils from this section has been observed: *Dicksoniaceaesporites* sp., *Cicatricosisporites* sp., *Sapindaceaepites dubia, Nymphaeaceaepites rarispina, Rhamneaepites minuta, Birbalipites pseudodrimys, Coniferaepites* sp., *Hystrichosphaeridium* sp. (numerous), etc., (pl. no. 2).

A. M. N. Ghosh (1940) has reported the following macrofaunas from the Langpar "stage": casts of gastropods *Xenophora, Cinula, Apphorais, Cyprea, Turritella;* pelecypod *Corbula;* echinoid *Hemiaster;* scaphopod *Dentalium;* cephalopods *Pachydiscus,* (?) *Baculites,* (?) *Nautilus* (*Hercoglossa*) *"danicus."*

The age limits of the Langpar Formation in its type occurrence are unknown, as no paleontologic study of the type section of the formation has so far been attempted.

Available paleontologic data indicate that in the southern scarp sections the Langpar Formation ranges in age between the Uppermost Cretaceous to approximately the base of Paleocene, i.e. the time interval represented by the uppermost part of Maestrichtian, and Danian, of common usage implying the transition of Upper Cretaceous and Paleocene. However, Loeblich and Tappan (1957) have demonstrated that the type Danian Stage is featured by the same planktonic foraminiferal assemblages as occurring in the type Montian Stage, and therefore, have considered both of these stages to be Lower Paleocene. Following them, Nagappa (1960) has considered the *Globigerina pseudobulloides* — G. *triloculinoides.* Assemblage-Zone of the Indus Basin and of the Bengal Basin, of the Langpar Formation in particular, as Lower Paleocene, and, further, Nagappa considered the *Miscellanea miscella* Range-Zone (more or less coeval with *Globorotalia wilcoxensis—G. velascoensis* Assemblage-Zone) as Upper Paleocene. It will be appreciated that in the problem of demarcating the top of Cretaceous and the base of Paleocene, the classical question involved is whether time should be equated to faunal zones or not. And in equating time with faunal zones, of course, we have to take into cognizance the facts that the associated faunas are diverse phylogenetically, and that the time range of the same species varies from zero (in unfavourable depositional habitats) to a finite maximum depending on the depositional basin position of the strata. It may be mentioned that the upper part of the *Rzehakina epigona* Range-Zone is represented in the basinal marl and shale facies in between the *Globigerina pseudobulloides — G. triloculinoides* Assemblage-Zone (overlying *Globotruncana contusa* Range-Zone) and *Globigerina wilcoxensis—G. velascoensis* Assemblage—Zone of the region between the Khirthar Range and Parh Range of the mobile belt of the Indus Basin, and that a similar foraminiferal succession may at least be expected to occur in areas depositionally downdip from Therria Ghat. The question relevant in this context is, should the *Globigerina pseudobulloides* Range-Zone be regarded as Lower Paleocene, the upper part of the *Rzehakina epigona* Range-Zone be regarded as Middle Paleocene, and the *Miscellanea miscella* Range-Zone be regarded as Middle Paleocene, (although in its original usage Schimper employed the term Paleocene, as pointed out by Loeblich and Tappan, in designating the littoral Bracheux sands and non-marine lignite beds of Soissons of Paris Basin)? In view of the different senses in which the term Paleocene is used, and of the fact that the type Danian Stage itself is identified on the basis of faunal contents, it is perhaps better to say that the Langpar Formation of the southern scarp section incorporates the upper part of the *Globotruncana stuarti* Range-Zone and is overlain without a diastem by the *Miscellanea-miscella* Range-Zone, thereby leaving the choice of age designations of this time interval to the individual opinion of paleontologists and stratigraphers. And we have to recognise after all that Maestrichtian, Danian etc. are fundamentally rock units in their respective type areas.

A basinal marl facies corresponding to the upper part of the Mahadeo Formation and to the lower part of the Langpar Formation is developed in the informally designated Akral Limestone of Taupokpi (24° 15′ N : 93° 53′ E) in Manipur, possibly in the Mai-i Group of Arakan Yoma, and in the undesignated basinal marls of Colinpur, South Andaman Islands, pl. 3.

The Langpar Formation was deposited in a steeply sloping marine shelf in the Khasi depositional trough, so much so that the bryozoan open marine shelf facies of the type area changes to a neritic shelf facies in the southern scarp sections. The faunas from the southern scarp occurrences of the Langpar Formation include species that are widely distributed throughout the Mediterranean and Caribbean regions, and reveal that, in the comparatively uniform deeper open marine habitats, even the benthonic species, such as, the arenaceous foraminifer *Frankeina taylorensis,* attain a global distribution.

Stratigraphic Status: Langpar Formation has been designated variously as the Langpar "band", Langpar "stage" and Langpar "bed". Considered rock stratigraphically it is a mappable rock unit of the formation rank, although in respect of time it seems to be a dspositionally down-dip facies variant of part of the Mahadeo Formation, and of the entire Cherra Formation of the Cherrapunji Plateau. Occasionally, the upper part of the Langpar Formation has also been treated by some previous workers as the "Cherra Stage", and even as the lower part of the "Sylhet Limestone stage", but such designations are informal in the opinion of the writer.

CHERRA FORMATION

Author: Medlicott, H. B., p. 169, 1869.

Type Section: The formation owes its name to the Cherra village (25° 17′ N : 91° 44′ E) in the Cherrapunji Plateau, where it is typically developed.

Typical Sections: No typical sections have so far been designated. In view of the thinning and wedgeout of the formation towards the north as well as to the south, at least two typical sections representing the northern and southern limits of the formation should be designated. Similarly, several typical sections illustrating the east-west lateral variation of the formation should be worked out on the basis of additional field work.

Lithology : In the type section the formation, according to Medlicott, is constituted of coarse feldspathic sandstones, with "some vague stemlike noncarbonaccous vegetal impressions", and of mottled clays. The formation has a similar lithology elsewhere in the Cherrapunji Plateau.

It may be mentioned in particular that there are no limestones or coal in the Cherra Formation proper. There are some previous records of the occurrence of limestones and coal from the "Cherra Sandstone stage". It is the opinion of the writer that such previous reports of coal from the Cherra Formation north of Surarim (25° 21′ N : 91° 44′ E) are from an unoccupied formation largely overlying the Cherra Formation *sensu stricto;* similarly occurrences of coal reported from the Cherra Formation east or south of the Cherrapunji Plateau are from the lower or middle member of the Sylhet Limestone Formation, as are the informally designated Cherra coal of Cherrapunji. Further, the previous reports of occurrence of limestones from the Cherra Formation are really limestones mostly belonging to the basal part of the Sylhet Limestone Formation, and in some instances to the lower, even the middle member of the Sylhet Limestone Formation.

Lower Contact : The Cherra Formation conformably overlies the Langpar Formation.

Upper Contact : The Cherra Formation is conformably overlain by the Sylhet Limestone Formation in the type area. It may be mentioned that the lower part of the Sylhet Limestone Formation developed in the Cherrapunji area consists of: (1) 80 feet thick basal limestone member with *Miscellanea miscella* and (2) 80 feet thick lower member with less than 10 feet thick coal in the lower part ("Cherra coal" of popular usage), overlain by 70 feet thick sandstones.

Structure : Considered regionally, the Cherra Formation is very gently dipping to the south. In areas downdip of the fault, south of Mahadeo (25° 13′ N : 91° 39′ E) and Nongwar (25° 13′ N : 91° 39′ E), the Cherra Formation seems to pass gradually into the Langpar Formation by depositional facies changes.

Thickness and areal distribution : The formation is 200 feet thick in the type area. North of Cherrapunji the sandstones of the Cherra Formation become coarser and in the vicinity of Surarim (25° 21′ N : 91° 44′ E) the formation becomes inseparable from the underlying conglomeratic beds. The Cherra Formation has a restricted distribution within the Cherrapunji Plateau. The sandstones occurring north of Surarim are lithologically similar to the sandstones of the Cherra Formation but apparently are rock stratigraphically unrelated to the latter. Therefore, the northerly distribution of the Cherra Formation is thought to be much more limited than indicated by Fox, A. M. N. Ghosh and Medlicott. The Cherra Formation is unrepresented in the Therria Ghat section, as originally mentioned by Medlicott (1869) and as accepted by Fox (1936a). Subsequently, however, Fox and A. M. N. Ghosh included the basal limestones and overlying sandstones of the Sylhet Limestone Formation of the Therria Ghat area within their extended "Cherra Sandstone stage", (1936b, 1940). Medlicott extended the Cherra Formation to the Garo Hills, but as indicated by Fox and Ghosh the coal-bearing sandstones underlying the Siju Member of the Sylhet Limestone Formation of the Garo Hills really constitute an entirely unrelated rock unit, namely, the Tura Formation (1937, 1954).

The factor controlling the spatial distribution of the Cherra Formation seems to be the clastic sedimentation phase of the Cherrapunji Plateau associated with the cycle of marine regression in the time span represented by the top of the Langpar Formation and the base of the Sylhet Limestone Formation. Updip of the Cherrapunji Plateau this phase of clastic sedimentation coincides with the preceeding and succeeding cycles also of arenaceous sedimentation; downdip of the Cherrapunji Plateau this phase of sandstone deposition is substituted by a cycle of essentially uninterrupted argillaceous sedimentation.

Fossils, age, paleoecology: No fossils, except fragmentary and poorly preserved fossil plant remains reported by Medlicott, are known as of date from the Cherra Formation proper.

In the absence of specific paleontologic information the precise age limits of the formation are unknown. But the facts that it overlies as well as represents an updip facies of the topmost Cretaceous ("Maestrichtian") sediments and underlies definite Paleocene (Upper Paleocene according to some authors) *Miscellanea miscella* Range-Zone indicate that the formation varies in age within the range uppermost Cretaceous and lowermost Paleocene.

In the absence of fossils it is difficult to interpret the precise depositional environment of the Cherra Formation. However, as the Cherra Formation lies in between the marine Langpar Formation and the marine basal member of the Sylhet Limestone Formation, and as it also represents a cycle of marine regression, it may be guessed that Cherra Formation is largely a freshwater deposit, with a possibility of association of some littoral sandstones at its top and base.

Sporepollen investigations of the argillaceous interbeds and interlaminations of the Cherra Formation should yield very interesting information bearing on the age and depositional environment of the rocks constituting the formation.

Stratigraphic Status: As originally defined this stratigraphic unit, although relatively thin, is a mappable lithologic unit with a well defined lower and upper sedimentary interface, and as such, it has been regarded as the Cherra Formation in this study. However, in view of the limited areal extent of this stratigraphic unit, and in view of the lack of specific field knowledge, the writer is not competent to judge whether a smaller rank, such as, a lentil might be more appropriate for this rock unit.

Previous designations, such as, the Cherra "band", "Cherra Sandstone stage", "Cherra stage", are informal in the judgement of the writer. Reasons have been forwarded elsewhere in this paper for restricting this lithologic unit vertically and areally to its original stratigraphic connotation, rather than extending it laterally and vertically in a misleading time-rock sense that has created considerable confusion - in the past. Infra nummultic coal-bearing sandstones, of the Garo Hills have already been demarcated from the Cherra Formation as an unrelated stratigraphic unit. Similarly, the infra-Nummulitic sandstones of the Mikir Hills may be designated as a separate rock unit, such as, the Mikir Formation, or by some other more suitable name.

TURA FORMATION

Author: Fox, C. S., 1937, (in Heron, 1937, p. 90).

Type Section: The formation derives its name from outcrops on the southern side of the Tura (25° 31′ N : 90° 15′ E) Range, Garo Hills.

Typical Sections: No typical sections have been formally designated for the Tura Formation by previous workers. In view of the fact that the formation is developed to the north of the Tura Range in the Daranggiri (25° 27′ N : 90° 42′ E) coalfield as well as to south of the Tura Range, that Fox based his definition of the formation partly on the characteristics of the formation in the Siju Songmong River section (25° 11′ N : 90° 39′ E), that the formation is developed in the isolated Rongrenggiri (25° 34′ N :

90° 33′ E) coalfield, and that Dr. Fox recorded the occurrence of coal-bearing sandstones of the formation from Rajai (25° 12′ N : 91° 14′ E) Barsaura (25° 12′ N : 91° 11′ E), Rileng market (25° 14′ N : 91° 13′ E) and Nongmawhar (25° 13′ N : 91° 11′ E) in the vicinity of the Jadukata River, it is suggested that at least four typical sections be designated from the Rongrenggiri, Daranggiri, Siju Songmong River section and Barsaura-Rajai areas.

Lithology: The formation consists of coarse, cross-bedded sandstones, with thin, lenticular interbeds of lignite and with kaolin at the base in the section exposed in the road extending between Tura and Dalu (25° 11′ N : 90° 14′ E). Fox has recorded the occurrence of three sandstone beds of the order of 200 feet thick each, with two interbedded coal seams of the order of 5 feet thick each, from the Siju Songmong River section.

Dominant sandstones with thin interbeds of lignitic coal and coal form the characteristic lithology of the formation.

Lower Contact: The Tura Formation has an erosional contact with the underlying gneissic and granitic Precambrian basement complexes. Fox records that in the Jadukata River section the Tura Formation is "underlaid by sandstones of Upper Cretaceous age" and that "these Mesozoic rocks in turn overlie beds of basaltic lavas and volcanic ash which are correlated with the Sylhet Trap", (1939, p. 56).

Upper Contact: The Tura Formation is gradationally overlain by the Siju Member (the base of which latter is Middle Eocene in age) of the Sylhet Limestone Formation.

Structure: The Tura Formation is developed on either side of the hoist block of the gneissic Tura Range, the northern flank of which is characterised by the Darang normal fault and the southern side by the Dapsi reversed fault (identified by Fox, 1937). The faults apparently developed in the Lower Eocene times initiating the deposition of the Tura Formation. These faults seem to have been active throughout the deposition of the formation. Post-depositional movements also occurred along the Dapsi fault and along some of the numerous smaller faults associated with the Tura Formation. The Dapsi reversed fault, for instance, is associated with the upturning of the Tura Formation, and also by an over-riding of the Tura Formation by the gneissic rocks of the Tura Range at the fault contact. In Dr. Fox's words, "there is always the upturned Tura stage under the gneisses at the foot of the Tura range; then follows a flat anticline; next a width of gently inclined beds and finally steep dips which quickly take the whole of the Eocene strata under Upper Tertiary sandstones". There are some north-south faults with considerable displacements and also many local faults, with smaller throws, characterising the formation. The entire Garo Massif (as also the adjoining ones) undoubtedly has been subjected to vertical block movements not only in the lower Eocene times but in Middle-Upper Eocene and post-Eocene times also. Some of the minor, more northerly, detached occurrences of the Tura Formation might have been formed in residual topographic basins, associated or otherwise, with faults.

The contrasted nature of development of the Cretaceous-Eocene formations to the east and west of the Jadukata River indicates a differential structural control of the original basins of deposition frontal to the Garo, and to the Khasi Hills along this region.

Thickness and areal distribution: The thickness of the Tura Formation in the Tura-Dalu road is of the order 300 feet, and further downdip in the Simsang River section (25° 11′ N : 90° 39′ E), it is of the order of 600-800 feet (in excess of 380 feet according to Ghosh, 1954). The thickness of the Tura Formation in the western edge of the Daranggiri coalfield at Darang Rongmuthupathal (25° 27′ N : 90° 43′ E) is in excess of 300 feet (Ghosh, 1954, after Arogyaswamy). The writer has not come across any published estimate of the thickness of the formation in the Rongrenggiri coalfield. In the stream sections of the Garo Hills, usually two seams of coal occur in the Tura Formation. The thickness of these two seams of coal is variable, the lower seam being often thicker and of commercial interest but seldom exceeding 9 feet in thickness.

The Tura Formation is fully exposed in the stream sections from west to east in the Dareng River (25° 19′ N : 90° 30′ E), Simsang River (25° 21′ 10″ N : 90° 42′ E), Rongra River (25° 13′ N : 90° 47′ E), Mahadeo River (25° 10′ N : 90° 54′ E), Maheskhali River (25° 10′ N : 90° 59′ E), in the Rupa Chara-Bagali Chara (25° 12′ N : 91° 02′ E) and according to Fox, in the vicinity of the Jadukata River (25° 14′ N : 91° 13′ E).

Thus the Tura Formation has a distribution south of the Precambrin massif of the Garo Hills, interrupted in the middle by the Tura Range horst block, and it apparently extends downdip as subcrops under the cover of Younger Tertiary sections to an unknown distance to the south.

Fossils, age, paleoecology: Only fossils reported so far from the Tura

Formation are macroscopic remains of fossil plants, including those of *Euphorbiaceae,* from the Rongrenggiri (25° 34′ N : 90° 33′ E) coalfield (Jacob in West 1949). Lakhanpal has identified from the plant fossils collected by Fox from the Tura Formation of Damalgiri (25° 32′ N : 90° 7′ E) the following forms: *Trema garoensis* Lakhanpal (*Ulmaceae*), *Neolitsea sahnii* Lakhanpal (*Lauraceae*), *Grewia foxii* Lakhanpal (*Tiliaceae*), *Bombacites orientalis* Lakhanpal (*Bombacaceae*), and *Nelumbium,* (1954, 1955). The beds containing these fossil plants are presumbly overlain by the attenuated, nearshore development of the Siju Member of the Sylhet Limestone Formation (Fox, 1936b).

Many species of fossil pollen described and illustrated in this paper, (pls. 5—9), from the Tura Formation of the Tura—Dalu Road section can be pollenmorphologically identified with their living generic counterparts, or with their natural families, thriving to-day in the rain forests of Assam, (an account of the modern floras and floral habitats of Assam is given by Kanjilal et al, 1934). Fossil pollen from the second clastic interbed of the Sylhet Limestone Formation of the Therria Ghat section are also described and illustrated in this paper, (pls. 10—13), with a view to record the close fossil pollen correlation that exists between the type occurrence of the Tura Formation and the middle member of the type occurrence of the Sylhet Limestone Formation in the Therria Ghat section. The second clastic interbed of the Sylhet Limestone Formation of the Therria Ghat section is underlain by a Lower Eocene larger foraminiferal biozone and is overlain by a Middle Eocene larger foraminiferal biozone (*Orbitolites complanatus —Nummulites cf. atacicus* Assemblage-Zone, and *Assilina papillata, Alveolina elliptica var. flosculina* Assemblage-Zone respectively). Therefore, on the evidence of nearly identical assemblages of fossil pollen occurring in the type section of the Tura Formation and in the known Lower—Middle Eocene clastic interbeds of the middle member of the Sylhet Limestone Formation, a contemporaneity between these two stratigraphic levels may logically be inferred. A further corroboration in support of such an inference is provided by the facts that (1) in all stream sections examined in the Garo Hills the *Assilina papillata, Alveolina elliptica var. flosculina* Assemblage-Zone transitionally overlies the Tura Formation, and that (2) the Lower —Middle Eocene pollen zone of the Tura Formation maintains more or less an identical character not only along the entire shelf area of the Bengal Basin from one end to the other but some of the index species of sporepollen from this zone are identical with those described from the Lower Eocene of Dandot in the Salt Range (Vimal, 1952), of Palana in Rajasthan (Rao and Vimal, 1952), of Barmer, Rajasthan (Bose, 1952) and of Dandot and Palana as described by Rao

(1955). It is interesting to note in this context that Fox did suggest an Eocene age for this formation, and that, A. M. N. Ghosh further indicated a possible Lower—Middle Eocene age of the Tura Formation.

A study of the fossil sporepollen of the Tura Formation suggests a possibility of occurrence of abundant macroscopic remains also of fossil plants in the Tura Formation, conceivably of the same order of richness and variety as recorded by Berry for the Wilcox Formation (1916). The more or less completely land locked basins north of the Tura Range and of other parts of the Garo Hills, appear to be the more suitable places for a painstaking search for such remains, as also a fertile ground for interesting research.

An analysis of the fossil floras of the Tura Formation, as revealed by their pollen contents, indicates the presence of herbs, shrubs as well as trees. Marshy and aquatic elements are dominant (particularly *Araceae, Lentibulariaceae, Potamogetonaceae, Nymphaeaceae* etc.), possibly growing right within the basin of deposition. The associated shrubs and trees seem to have been flourishing in the adjacent uplands of the Tura Range and in the gneissic massif areas, adjoining the basin margin (such as the *Combretaceae, Tiliaceae, Rubiaceae, Utricaceae, Caesalpinae, Santalaceae, Proteaceae, Rutaceae* etc.). The occurrence of hystrichospherids suggests a periodic brackish water influence characterising the coal basin, and it is not known whether the associated palm pollen were derived from seaside *Palmae*. Sparse conifer pollen occurring in the sporepollen assemblages of the Tura Formation suggest their drifted nature, apparently from far away hilly areas outside of the Bengal Basin. Berry (1916), Wodehouse (1932, 1933) and Chandler (1923-24) have demonstrated how a study of fossil plants and pollen can be applied in a vivid restoration of the paleogeography of the depositional basin of the Wilcox Formation, Green River Formation and Upper Eocene of Southern England respectively, and the same approach is equally applicable in a concrete understanding of the configuration of the depositional basins of the Tura Formation. The indigenous floral elements of the Tura Formation are overwhelmingly of a humid tropical rain forest type, flourishing and flowering in the marshes and uplands of the Garo Hills at a time, when, thriving in the adjacent contemporaneous Khasi—Jaintia trough south of the Cherrapunji Plateau were teeming millions of warm, shallow marine, clear water semi-reefal assemblages of *Alveolina*, miliolids, *Rotaliids* of the *Dictyoconoides* type, *Opertorbitolites*, calcareous algae etc. The topography around the southwestern corner of the modern Chilka lake, in the judgement of the writer, furnishes a fair idea of the depositional topography (and, of course, not of the tectonic setup) associated with the Tura Formation, with the shores of Lower—Middle Eocene sea lapping around the Garo Massif some distance further south compared to its more northerly extension in the Khasi—Jaintia Hills. Whereas the extensive development of Middle Eocene limestones, overlying the Tura Formation and its contemporaneous deposits along the entire shelf region between the Garo and Mikir Hills, and the occurrence of coaly deposits underlying and associated with these limestones may be utilised as a reliable "paleotopographic meter," so to say, in interpreting a subdued the then topographic relief of large parts of the Shillong Plateau, the nature of updip variation of the depositional facies of sediments of this age suggests a confinement of the Eocene marine transgressions well within the Shillong Plateau as inferred by Medlicott (1869), rather than their extension across the Shillong Plateau as postulated by Fox (1936 b).

Stratigraphic Status: The rock successions of this stratigraphic unit constitute a mappable rock unit, extending from the western part of the Garo Hills to the vinicity of the Jadukata River in the western part of the Khasi Hills, as also occurring north of the Tura Range. It may accordingly be treated as the Tura Formation. It is essentially in this sense that Fox proposed this stratigraphic unit, and previous designations of this formation as the "Tura sandstone stage," "Tura stage" and "Tura beds" appear to be informal, judged in the context of systematic stratigraphic nomenclature. It may be emphasised that the Tura Formation does not extend east of the Jadukata River as a mappable rock unit and, therefore, it is unrepresented as such in the Khasi and Jaintia Hills. It has no conceivable rock stratigraphic relationship with the Cherra Formation proper.

SUMMARY AND CONCLUSIONS

It will be obvious from a review of the foregoing discussions that the Garo, Khasi-Jaintia and Mikir Hills were characterised by differential tectonic movements in course of the Upper Cretaceous and Lower Eocene times, with the result that the pattern of sedimentation featuring these regions during this interval of time has been different. In the Middle and Upper Eocene times a certain homogeneity of the nature and pattern of tectonic deformation was characteristic of the entire region between the Garo and Mikir Hills, accounting thereby for a greater similarity in the nature of the associated sediments.

Thus in the Upper Cretaceous times, when the Khasi Block and the western part of Jaintia Block were undergoing subsidence and marine transgression, the other adjoining areas of the Shillong Plateau stood high enough for erosion. Also with an abrupt steepening of the shelf, and, therefore, of the deepening of the ocean floor south of the Cherrapunji Plateau in the topmost Cretaceous times, there was a dominantly sandy deposition in the Cherrapnji area but a concomittant dominantly argillaceous sedimentation in the environs of Therria Ghat. In the Paleocene times the more eastern parts of the Jaintia Block caught up with the Khasi Block in the rate and manner of subsidence and both of these regions were characterised by a more or less similar pattern of sedimentation in the Paleocene Epoch, although at this time the Garo and Mikir Blocks were sites of no subsidence and, therefore, of no deposition. In the Lower Eocene and in the lower part of the Middle Eocene times the Garo and Mikir Blocks also started subsiding, but a higher topographic relief at the basin margin of these two blocks and the very gently dipping nature of the adjoining shelf areas accounted for the dominantly freshwater sandy deposition in the Garo and Mikir Hills, whereas in the extended arm of the sea in the Khasi-Jaintia Block with a subdued basin margin topography at this time, a larger proportion of limestones and a lesser proportion of sandstones were deposited. Thus, there is a basic difference in the pattern as well as in the characteristics of Upper Cretaceous—Lower Eocene sedimentation itself in the Garo, Khasi and Mikir Blocks.

The ultimate purpose of a systematic rock stratigraphic breakdown is to map the spatial and vertical extents of similarity and dissimilarity of contemporaneous sediments in different areas as a measure of the trend and tempo of tectonic deformation characteristic of different basin positions. The history of differential tectonic deformation of the Garo, Khasi, Jaintia and Mikir Hills in course of the Upper Cretaceous—Lower Eocene times, as outlined in the preceeding paragraph, is written in the sedimentary rocks themselves of these areas. Viewed from this angle, it will be obvious that the contrasts in the Upper Cretaceous—Lower Eocene rock units of the Garo, Khasi, Jaintia and Mikir Blocks, or of the northern and southern parts of the Khasi Blocks are inherent in the contrasted pattern of contemporaneous tectonic deformation characterising these areas.

The Mahadeo, Langpar and Cherra Formations were initially proposed for specific successions of rocks in the Cherrapunji Plateau and environs. Subsequently on the basis of inferred ages of these rock units in the Cherrapunji Plateau (incompletely known at that time), attempts were made to extend these units to the northern and southern part of the Khasi Hills and to the Garo Hills to other rock successions, assuming a continuity that in fact did not exist, resulting in considerable confusions as to their status and distribution. As paleontological evidence has been available from the more marine sections to the south, attempts have been made to equate some of previous stratigraphic units with the paleontological zones, and several additional stratigraphic units have been proposed on the basis of paleontologic zones subsequently discovered, with the result that the existing classification of these rock successions of the Garo, Khasi and Jaintia Hills suffers from an imbalance inherent in a dual basis of classification.

The approach adopted in this study is to classify these stratigraphic units strictly on a lithologic basis, irrespective of the age of the beds, or of their fossil contents (fossil contents have been utilised only in the identification of beds of the same lithology in areas of detached outcrops). It is believed that an approach such as this not only resolves the existing confusions in respect of the stratigraphic classifications of these rock successions, but brings out the differential geological history of this region with a reasonable degree of clarity.

It has been inferred that:

1. The Mahadeo Formation is a mappable rock unit in the Khasi Hills and in the Jaintia Hills. In the southern areas the upper part of the Mahadeo Formation becomes increasingly shaly, finally pertaking of the lithological characteristics of the Langpar Formation.

2. The Langpar Formation is a mappable rock unit in the Khasi—Jaintia Hills. It is thicker in the southern scrap sections, and its upper part there represents, timewise, the Cherra Formation of the Charrapunji Plateau.

3. The Cherra Formation is a mappable lithologic unit in the Cherrapunji Plateau. It shalesout in the southerly direction to merge with the Langpar Formation and is unrepresented as such in Therria Ghat. Some 4-5 miles north of Cherrapunji, the Cherra Formation becomes indistinguishable from the underlying clastic sequences. The stratigraphic unit developed north of Surarim, with overlapping relationship with the Mahadeo, Langpar and Cherra Formation sensu stricto, that has been treated as the "Cherra sandstone stage" in the previous literature, is to all appearances a separate undesignated formation (an updip clastic development largely contemporaneous with the Sylhet Limestone Forma-

tion). Similarly the infra-Nummulitic sandstone beds of the Mikir Hills constitute a separate undesignated formation, unrelated rock stratigraphically to the Cherra Formation.

4. The Tura Formation is a mappable rock stratigraphic unit developed in the Garo Hills and it does not extend as such to the east of the Jadukata River. Timewise, the Tura Formation is the time equivalent of the lower and middle (lowerpart) members of the Sylhet Limestone Formation of the Khasi—Jaintia Hills.

5. The basal member of the type occurrence of the Sylhet Limestone Formation in the Khasi Hills is a local development in the Khasi—Jaintia Hills, unrepresented in the Garo and Mikir Hills. Similarly, the lower member of the Sylhet Limestone Formation of the Khasi—Jaintia Hills is represented by a contrasted lithological facies in the Garo and Mikir Hills.

6. The middle (upper part) and upper members of the Sylhet Limestone Formation of the Khasi Hills have a basinwide distribution, and are represented by the more or less monotonous limestone sequences of the Siju Member of the Sylhet Limestone Formation in the Garo Hills, and by the Prang Member as well as by the dominantly argillaceous rocks of the lower part of the Kopili Formation in the Jaintia Hills.

Acknowledgements

The writer is indebted to Standard-Vacuum Oil Company, and specially to Mr. R. G. Prough for permission to publish this paper, for his encouragements, and for making the ACSN "Code of Stratigraphic Nomenclature" available. The writer is grateful to Mr. J. M. Dorreen for initiating him into the systematics of stratigraphy and to Mr. J. Kingston for the material. Thanks are due to Mr. H. Trattner for going through the manuscript and for his criticisms. Mr. B. N. Das kindly drafted the illustrations and Mr. S. K. Chatterji took the photomicrographs. Prof. N. N. Chatterjee and Shri A. Chaudhuri of the Department of Geology University of Calcutta, and Shri Sripati Bhattacharjee of the World Press Private Ltd. kindly offered various helps and suggestions in the publication stage.

SELECTED BIBLIOGRAPHY

American Commission of Stratigraphic Nomenclature, 1961: Code of Stratigraphic Nomenclature, Bull. Amer. Assoc. Petrol. Geol., Vol. 45, No. 5, p. 645-665.

Berry, E. W., 1916 : The Lower Eocene Floras of Southeastern North America, Prof. Paper, No. 91, U.S.G.S., p. 1-481, pls. 107 text. figs.

Bose, M. N., 1952 : Plant Remains from Barmer District, Rajasthan, Jour. Sci. Indus. Res. (India), vol. 11, Sec. B., p. 183-190, figs. 1 and 2.

Brown, C. A., 1957 : Comments on European Tertiary pollen studies, Micropaleontology, Vol. 3, No. 1, p. 81-83.

Chandler, M. E. J., 1923-24 : "The Upper Eocene Flora of Hordle, Hants," Paleontographic Society (Britain), pts. I-II, vols. 77-78, p. 1-32, 33-55, pls. I-IV, V-VIII, p. i-vii.

Chandler, M. E. J., 1923 : The Geological History of the genus *Stratiotes* etc., Quart. Jour. Geol. Soc. Lond., vol. 79, p. 117-138, pls. 5-6.

Chitaley, S. D., 1951 : Fossil Microflora from the Mohgaon Kalan Beds of the Madhya Pradesh, India, Proc. Nat. Inst. Sci., vol. 15, p. 373-383, pls. 13-15, figs. 1-28.

Couper, R. A., 1953 : Upper Mesozoic and Cainozoic spores and pollen grains from New Zealand, New Zealand Geol. Surv., Pal. Bull., No. 22, p. 1-77, pls. 1-9.

Das, K. L., 1940 : On the Cherra-Nummulitic sequence, near Cherrapunji, Quart. Jour. Geol. Min. Met. Soc. India, vol. 12, No. 1, p. 15-18, figs. 1-3.

Das Gupta, H. C., 1926 : Paleontologic Notes on the Nummulitic rocks of Cherra-Punji, Khasi Hills, Jour. Dept. Sci. Cal. Univ., vol. 8.

Das Gupta, H. C., 1929 : A Short note on the Cretaceous fauna of tht Khasi Hills, Quart. Jour. Geol. Min. Met. Soc. India, vol. 2, No. 1, p. 25-34, pls. 1-2.

Erdtman, G., 1943 : An Introduction to Pollen Analysis, Chronica Botanica Co.

Erdtman, G., 1952 : Pollen Morphology and Plant Taxonomy, Chronica Botanica Co.

Evans, P., 1932 : Tertiary Succession in Assam, Trans. Min. Geol. Inst. India, vol. 27, pt. 3, p. 155-260, map, 1 table, figs.

Fox, C. S., 1936a : (In L. L. Fermor) Director's General Report for 1934, Rec. Geol. Surv. India, vol. 69, pt. 1, p. 82-84.

Fox, C. S., 1936b : (In A. M. Heron) Director's Gen. Rpt., (idem), vol. 71, pt. 1, p. 81-86.

Fox, C. S., 1937 : Idem, Vol. 72, pt. 1, p. 85-90.

Fox, C. S., 1938 : (Rec. Geol. Surv. Ind.). Vol. 73, pt. 1, p. 75-80.

Fox, C. S., 1939 : Idem, Vol. 74, pt. 1, p. 55-63.

Ghosh, A. K., 1940 : Fossil Pollen in the Tertiary Rocks of Assam, Sci. and Cult., Calcutta, Vol. 6, No. 11, p. 674, fig. 1.

Ghosh, A. M. N., 1936b : See under Fox (1936b).

Ghosh, A. M. N., 1937 : See under Fox (1937).

Ghosh, A. M. N., 1938 : See under Fox (1938).

Ghosh, A. M. N., 1939 : See under Fox (1939).

Ghosh, A. M. N., 1940 : The Stratigraphical Position of the Cherra Sandstone, Assam, idem, Vol. 75, Prof. Paper No. 4, p. 1-19, pls. 1-4, 1 geol. map.

Ghosh, A. M. N., 1954 : The Tura Sandstone Stage of the Garo Hills—its possible Stratigraphical Position, idem, Vol. 83, pt. 2, p. 423-444.

Holland, T. H., 1926 : Indian Geological Terminology, Mem. Geol. Surv. Ind., Vol. 51, pt. 1, p. 55.

Jacob, K., 1949 : (In W. D. West) Director's Gen. Rpt. for 1948, idem, Vol. 82, pt. 1.

Kanjilal, U. N. et al, 1934 : Flora of Assam, Vol. 1, pt. 1, Govt. of Assam, p. 1-184.

Kuyl, O. S., J. Muller & H. Th. Waterbolk, 1955 : The Application of palynology to oil geology with special reference to western Venezuela, Geologie en Mijnbouw, N.W.S., 17E Jaargang, No. 3, p. 49-75, pls. 1-8, figs. 1-28.

Lakhanpal, R. N., 1954 : Recognisable species of Tertiary plants from Damalgiri in the Garo Hills, Assam, The Paleobotanist, Vol. 3, p. 27-31, pls. 1-2.

Lakhanpal, R. N., 1955 : The occurrence of *Nelumbium* in the Tertiary of Assam, Jour. Indian Bot. Soc., Vol. 34, p. 222-224, figs. 1-4.

La Touche, T. D., 1889 : Report on the Cherra Poonjee Coal-field, Rec. Geol. Surv. Ind., Vol. 22, pt. 3, p. 167-171, (with a plan).

La Touche, T. D., 1890 : Report on the Lakadong Coal-field, Jaintia Hills, idem, Vol. 23, pt. 1, p. 14-17, (with two plans).

Loeblich, A. R. & H. Tappan, 1957 : Correlation of the Gulf and Atlantic Coastal Plain Paleocene and Lower Eocene Formations by means of planktonic foraminifera, Jour. Paleo., U.S., Vol. 31, No. 6, p. 1109-1137, figs. 5.

Medlicott, H. B., 1869 : Geological sketch of the Shillong Plateau, Mem. Geol. Surv. Ind., Vol. 7, pt. 1, p. 151-207, 1 geol. map., figs. 3.

Nagappa, Y., 1951a : A Note on H. C. Das Gupta's collection from the Nummulitic Limestone of Cherrapunji, Khasi Hills, Assam, Quart. Jour. Geol. Min. Met. Soc. India, Vol. 23, No. 4, p. 181-182, figs. 1-5.

Nagappa, Y., 1951b : The Stratigraphical value of *Miscellanea* and *Pellatispira* in India, Pakistan, and Burma, Ind. Acad. Sci., Proc., Sec. B, Vol. 33, No. 1, p. 41-48, figs. 2.

Nagappa, Y., 1956 : Foraminifera of the genera *Fabiania* and *Eorupertia* from the Sylhet Limestone of Assam, Pal. Soc. India, Vol. 1, No. 1, p. 191-198, text figs. 1-4, 1 geol. map.

Nagappa, Y., 1959 : Foraminiferal biostratigraphy of the Cretaceous-Eocene succession in India-Pakistan-Burma region, Micropaleontology, Vol. 5, No. 2, p. 145-192, text figs. 1-11, tables 1-19.

Nagappa, Y., 1960 : The Cretaceous-Tertiary boundary in India-Pakistan Subcontinent, Rpt. 21st Session Int. Geol. Cong., p. 41-49, fig. 1.

Mukherjee, P. N., 1939 : See under Fox (1939).

Oldham, T., 1859 : On the Geological Structure of a portion of the Khasi Hills, Bengal, Mem. Geol. Surv. India, Vol. 1, p. 99-210, pls. 419, figs. 1-22.

Oldham, T., 1863 : On the occurrence of Rocks of Upper Cretaceous age in Eastern Bengal, Quart. Jour. Geol. Soc. London, vol. 19, pt. 1, p. 524-526.

Palmer, R. W., 1923 : Geology of a part of the Khasi and Jaintia Hills, Assam, Rec. Geol. Surv. Ind., Vol. 55, pt. 2, p. 143-167, 1 geol map.

Radforth, N. W. & G. E. Rouse, 1954 : The classification of Recently Discovered Cretaceous Plant Microfossils of Potential Importance to the Stratigraphy of Western Canadian Coals, Canadian Jour. Bot., Vol. 32, No. 1, 187-201, pl. 1.

Rao, A. R., 1955 : Some observations on pollen found in Indian Tertiary lignites, The Paleobotanist, Vol. 4, p. 57-59, pls. 1-4.

Rao, A. R., 1958 : History of Botanical Researches in India, Burma and Ceylon, pt. 3., Paleobotany, p. 1-57, Indian Botanical Society.

Rao, A. R. & K. P. Vimal, 1952 : Tertiary Pollen from Lignites from Palana (Eocene) Bikaner, Proc. Nat. Inst. Sci. India, Vol. 18, No. 6, p. 595-601, pls. 17-18.

Rao, K. S., 1943 : Fossil Algae from Assam: 1. *Corallinaceae*, Proc. Nat. Acad. Sci. India, Sec. B, Vol. 13, p. 265-269, pls. 1-2, figs. 1-30.

Rao, K. S., 1947 : On the occurrence of algal genus *Dactylopora* in the limestones from Assam, Abs. Indian Sci. Cong., 34th Proc., pt. 3.

Sen, J., 1948 : The Coal Seam at Laitryngew and the age of the Cherra sandstone, Bull. Bot. Soc. Bengal, Vol. 2, p. 1-11, text figs. 1-33.

Selling, O., 1946 : Studies in Hawaiian pollen statistics, pt. 1, the spores of the Hawaiian pteridophytes, Spl. Publ., No. 37, Bernice P. Bishop Museum, p. 1-87, pls. 1-7.

Selling, O., 1947 : Idem, pt. 2, the pollen of Hawaiian Phanerogams, Spl. Publ., No. 38, p. 1-430, pls. 1-58.

Simpson, J. B., 1936 : Fossil Pollen in Scottish Tertiary Coals, Proc. Roy. Soc. Edinburg, Vol. 56, pt. 2, No. 7, p. 90-108, pls. 1-3.

Sitholey, R. V., 1954 : The Mesozoic and Tertiary Floras of India: A Review, The Paleobotanist, Vol. 3, p. 55-69, 1 table.

Spengler, E., 1923 : Contributions to the Paleontology of Assam, Mem. Geol. Surv. Ind., Pal. Indica, Vol. 8, p. 1-67.

Stoliczka, F., 1869 : (In H.B.Medlicott, 1869), Mem. Geol. Surv. Ind., Vol. 7, p. 181-183.

Thiergart, F., 1940 : Die Micropaleontologie als Pollenanalyse im Dienst der Braunkohlenforschung, Brennstoff-Geologie, No. 13, p. 1-82, pls. 1-14, 3 distrib. charts.

Traverse, A., 1956 : Systematic methods for Mesozoic and Cenozoic plant microfossils, Micropaleontology, Vol. 2, No. 4, p. 396-398, table 1.

Traverse, A., 1957 : The nomenclatural problem of plant microfossil species belonging to extant genera, Micropaleontology, Vol. 3, No.3, p. 255-258.

Vimal, K. P., 1952 : Spores and Pollen from the Tertiary lignites of Dandot, West Punjab, Pakistan, Proc. Indian Acad. Sci., Sec. B., Vol. 36, p. 135-147, pls. 5-8.

Wilson, G. F. & W. B. Metre, 1953 : The World's Oilfields : Assam and Arakan, The Science of Petroleum, Vol. 6, pt. 1, p. 119-123, 1 geol. map, 2 figs.

Wilson, L. R. & R. M. Webster, 1946 : Plant Microfossils from a Fort Union Coal of Montana, American Jour. Bot., Vol. 33, No. 4, p. 271-278, figs. 1-18.

Wodehouse, R. P., 1932 : Tertiary pollen I. Pollen of the living representatives of the Green River flora, Bull. Torrey Bot. Club., Vol. 159, No. 6, p. 313-340, pls. 20-22, figs. 1-12.

Wodehouse, R. P., 1933 : Tertiary pollen II. The oil shales of the Green River Formation, ibid., Vol. 60, No. 7, p. 479-524, figs. 1-54.

EXPLANATION OF PLATES

PLATE NO. I.

All figures are from the Mahadeo Formation of the Dauki area, age Uppermost Cretaceous (Upper Senonian).

Figure 1 : Medium-grained quartzo-feldspathic sandstone, with oxidised glauconite, shell fragments, and fragment of an Orbitoidal foraminifera; x30 diameters.

„ 2 : Fine-grained sandstone with ferruginous matrix, and a large grain of orthoclase; x30 diameters.

Figure 3 : Medium to fine-grained quartzo-feldspathic sandstone, with oxidised glauconite grains and smaller foraminifera; it is interesting to note that *Robulus* and *Lenticulina* had wide bathymetric distribution in the Upper Cretaceous times, comparable more or less to that of *Rotalia* since the Miocene Epoch. The sandstones represent sublittoral deposition; x30 diameters.

PLATE NO. II.

All figures are from feebly calcareous, yellowish green clayshales of the Langpar Formation of the Um Sohryngkew River section, age transitional between Uppermost Cretaceous and lower part of Paleocene.

Figure 1 : *Dicksoniaceaesporites* sp.; proximal compression; exine rather thin, smooth; longest diameter 33 microns.

„ 2 : *Cicatricosisporites* sp.; oblique compression; exine thick; ridges widely spaced; sporemorphologically related to various modern species of *Aneimia* (*Schizaceae*), *Ceratopteris* (*Parkeriaceae*) and to an extent to *Cyathea decipiens* (*Cyatheaceae*); it would be interesting to know if there is any phylogenetic relationship between these families; l.d. 44 microns.

„ 3 : *Cicatricosisporites* sp.; oblique compression; ridges close spaced; l.d. 72 microns.

„ 4 : *Sapindaceaepites dubia* sp. nov.; polar compression (in this paper polar region is considered to lie at or in the direction of convergence of the furrows or to lie at the join of the bisectrices of the angle of porate grains); exine moderately thick and reticulate; tricolporate, furrows tend to extend to the polar region; there is pollenmorphologic similarity with modern *Cardiospermum halicacabum*, but the furrows tend to be vestigial in this modern species; l.d. 29 microns; fossil leaves, fruits, seeds and pollen of the *Sapindaceae* are known from the Upper Cretaceous, Eocene and Oligocene of the U.S. Gulf Coastal basin, Uinta Basin, and Mediterranean basins of Continental Europe; holotype.

„ 5 : *Birbalipites pseudodrimys* gen. et. sp. nov.; single pollen grain; exine reveals zonation, the outer zone being thicker; exine reticulate; no definite ulcus, as visible in the modern species *Drimys winteri*, is discernible; occurrence of varied and abundant occurrence of the pollen of the *Magnoliaceae* in the Upper Cretaceous sediments of the Bengal Basin has also been considered in interpreting the phylogenetic affinity of this species; l.d. 51 microns; fossil remains of the *Magnoliaceae* are known ever since the Cretaceous times from many parts of the world, including the Eocene sediments of the modern Arctic region; holotype.

„ 6 : Tricolpate pollen grain, affinity unknown, has superficial morphologic resemblance with the pollen grains of *Ginkgo*; l.d. 36 microns.

„ 7 : *Nymphaeaceaepites rarispina* sp. nov.; exine moderately thick; spines comparatively few, short; germinating apparatus not clearly marked; botanists regard the *Nymphaeaceae* to be transitional between monocotyledons and dicotyledons; it has been observed that there is a certain degree of convergence pollenmorphologically between some of the primitive *Nymphaeaceae, Araceae, Alismataceae* etc.; l.d. 30 microns; holotype.

„ 8 : *Alismataceaepites rogalskai* sp. nov.; exine smooth, comparatively thin; aperture subperipheral; strong pollenmorphologic similarity with modern *Sagittaria sinensis*; *Alismataceae* is a primitive marshy-aquatic family; diameter 24 microns; holotype.

„ 9 : *Monocolpopites* sp.; equatorial compression; affinity unknown, l.d. 23 microns.

„ 10 : *Coniferaepites* sp.; weathered grain; l.d. 110 microns.

Figure 11 : *Rhamneaepites minuta* sp. nov.; polar compression; tricolporate; three radiate markings across the angles give rise to a syncolpate appearance; exine moderately thick; l.d. 15 microns; fossil leaves and fruits of *Rhamneae* are known from the Eocene-Miocene Epochs of the U.S. Gulf Coast and Continental Europe; holotype.

„ 12 : *Hystrichosphaeridium* sp.; diameter of the body 65 microns; length of the pads ± 15 microns; pads anastomosing at the tip.

„ 13 : *Hystrichosphaeridium* sp.; diameter of the body 52 microns; length of the pads ± 25 microns; pads entire.

PLATE NO. III.

Figure 1 is a thin section of a grey shale of the Langpar Formation of the Therriaghat Section.

Figurers 2-3 are thin sections of white fine-grained basinal marls of Manipur.

Figure 1 : Slightly calcareous foraminiferal shale with a lagenid foraminifer. These shales contain abundant Maestrichtian smaller foraminifera some of which have been mentioned in the text. The shales were deposited in a comparatively deep open neritic marine shelf; x30 diameters.

Figures 2-3 : Basinal marl with "porcellanic" appearance from the informally designated "Akral Limestones" of Taupokpi, with secondary calcite veins (fig. 3); these rocks are full of pelagic and bathyal-benthonic smaller foraminiferas; *Globigerina, Globotruncana, Pseudotextularia* etc. are the dominant foraminiferas in these rocks; it is difficult to identify the various species of *Globotruncana* from thin sections of these marls, but double-keeled forms, such as, *G. area* Cushman seem to be associated; these marls are also associated with serpentinised peridotitic intrusions; these marls seem to be more or less coeval with the calcareous shales of the Langpar Formation, illustrated in fig. 1; x30 diameters.

PLATE NO. IV.

All figures are photomicrographs of thin sections of fine-grained limestones, devoid more or less of macrofossils, from the basal member of the Sylhet Limestone Formation of the Umiam River section. Faunal contents of these rocks have been illustrated here in order to furnish specific paleontological evidence indicating a mappable relationship of the limestones of this member between Cherrapunji Plateau and the southern scarp sections.

Figures 1, 4 : *Miscellanea miscella* (d'Archiac and Haime) from partly recrystallised limestones that are often devoid of fossils, partly because of an initial comparatively poor faunal content and partly because of obliteration of fossils in the process of diagenesis; these limestones represent a shallow warm clearwater open marine shelf deposition below effective wave base in the localised Paleocene depositional trough of the Khasi Hills with a subdued the then basin margin topography; x30 diameters.

Figure 2 : *Alveolina primaeva* Richel from the same level as represented in fig. 1; *A. primaeva* is a widely distributed index species in sediments of comparable depositional habitats as well as in reefal habitats of the Mediterranean basins, as far as the Pyrenees region; x30 diameters.

„ 3 : *Orbitolites* sp. from the same level as represented in fig. 1; it may be mentioned that the updip occurrences of these limestones in the Cherrapunji Plateau are featured by a dominance of *Corallina grandis* (Das Gupta), *Distichoplax biserialis* (Dietrich) as well as of *Chlorophyceae,* further associated with a greater proportion of clastics, apparently indicating a periodic brachyhaline influence in the near-littoral depositional habitats of the updip areas; x30 diameters.

Figure 5 : *Lockhartia* sp. from the same level as represented by fig. 1; x30 diameters.

PLATE NO. V.

All figures are photomicrographs of sporepollen from the lignitic coal interbeds of the type occurrence of the Tura Formation in the Tura-Dalu Road Section. These sporepollen assemblages are characteristic of the Lower-Middle Eocene times in the Bengal Basin, and some of the index species illustrated here are also characteristic of the Lower-Middle Eocene of the Indus Basin. These sporepollen assemblages are typical of an essentially marshy habitat of more or less land-locked basins, periodically under brackish water influence. Natural generic names have been used in instances where obvious pollenmorphologic similarities with modern genera exist, alternatively the modern genus with which the fossil sporomorph has strong morphologic similarity has been used as a specific name of the fossil form to indicate such a relationship; in instances where it has not been possible to recognise pollenmorphologic similarities of the fossil sporomorphs beyond the family rank, natural families have been compounded with a suffix—sporites and—pites to deduce the generic designations; for all other stratigraphically significant species artificial morphologic genera of previous authors have been used.

Figure 1 : ***Dorreenipites platydesma*** gen. et. sp. nov.; polar compression; exine thick, faintly reticulose in the polar region, reticulate in the subequatorial region, finely papillate near the equatorial (?) girdle; characteristically anisopolar, prominent thickening of the endexine at the base of the pores; l.d. 39 microns; ***D. platydesma*** has morphologic similarity with the modern rain forest species ***Platydesma campanulatum*** Mann; fossil leaves of the ***Rutaceae*** have been described from the Eocene of the U. S. Gulf Coast and are common in the Oligocene of the Mediterranean region also; alternatively ***D. platydesma*** has morphologic similarity with ***Anaclosa lutea*** (*Olacaceae*) but the latter exhibits exine differentiation at the angles and sides, and is 6 forate; holotype.

„ 2 : *Ulmaceaepites garoensis* sp. nov.; polar compression; exine thick, tegillate; triporate, pores aspidote; l.d. 26 microns; fossil leaves of ***Trema*** have been described previously from the Tura Formation of the Garo Hills by Lakhanpal; doubtful remains of fossil leaves of *Ulmaceae* are described from the Eocene of Montana, U.S.A.; holotype.

„ 3 : ***Tricolporipites*** sp.; polar compression; exine thick, reticulate; length of the furrows 12 microns; l.d. 34 microns.

„ 4 : ***Tetracolpopites*** sp.; polar compression; exine thick, reticulate; (? ora 4 microns deep); l.d. 30 microns; has strong pollenmorphologic similarity with ***Fagoideae; Fagaceae*** had wide distribution in the Paleocene and Eocene times from the U.S. Gulf Coasts, Mediterranean region to New Zealand, as borne out by the prolific remains of its fossil leaves and fossil pollen; in the evergreen forests of Assam ***Fagaceae*** are quite common at the present day; it has not been possible to formally designate this fossil form in the absence of comparative studies with modern pollen.

„ 5 : ***Triporipites*** sp.; polar compression; exine comparatively thin, distinctly but finely reticulate; indistinct small pores in the angles, pores nonaspidote; l.d. 21 microns; should be an important index species in view of the readily recognisable characteristics but its natural family affinities could not be determined.

„ 6 : ***Pentacolpopites*** sp. B; polar compression; exine thick, reticulate; furrows ±8 microns long; l.d. 36 microns; as polycolpate pollen occur in many diverse families, precise natural affinities of this species and of many other associated abundantly occurring polycolpate forms could not be satisfactorily determined.

„ 7 : ***Wadiapites caryophylla*** gen. et. sp. nov.; polar compression; exine thin and very feebly reticulate; 6 fores recognisable, fores 9 microns across, with collar; l.d. 31 microns; it has general morphologic similarity with the modern pollen of *Drymaria cordata* (*Caryophyllaceae*) but the latter has rugate fores; ***W.***

caryophylla has some pollenmorphologic similarity with modern pollen of *Calystegia sepium* of the *Convolvulaceae*, and of *Drosera burmannica* Vahl. and *D. peltata* Sm. flourishing quite commonly on the leeside of modern sand dunes of the East Coast of India but fores are much less developed in the latter; holotype.

Figure 8 : *Pentacolpopites turaensis* sp. nov.; polar compression; exine thick, finely reticulate; furrows 4 microns long, very narrow; l.d. 24 microns; very common in the Tura Formation and in the contemporaneous freshwater clastic interbeds of the Sylhet Limestone Formation; in all probability belongs to the *Oleaceae*, and possibly to *Fraxinus*; related pollen have been recorded by Rao and Vimal from Lower Eocene lignites of Dandot and Palana; fossil remains of *Fraxinus* are known from the Eocene of the Atlantic Coastal Plain of U.S.A.; holotype.

„ 9 : *Tricolporipites tiliaceaeformis* sp. nov.; polar compression; exine thick, tegillate; furrows short; diameter 20 microns; fossil *Grewia* has been described by Lakhanpal from the Tura Formation; fossil *Tiliaceae* had worldwide distribution in the Eocene times, including the Arctic region, and are known also from the Oligocene and Miocene of the Mediterranean region; *Tiliaceae* are abundantly represented as herbs, shrubs and trees in Assam at the present day; holotype.

„ 10 : *Paleosantalaceaepites primitiva* gen. et. sp. nov.; equatorial compression; exine moderately thick, smooth; longitudinal furrows do not extend pole to pole, prominent, probably functional; width of the transverse furrow-ring 5 microns; 35×24 microns; has strong morphologic similarity with the pollen of modern *Exocarpus*, with the exception that in the latter the logitudinal furrows are vestigial; holotype.

„ 11 : *Monsteroideaepites eospathiphyllum* gen. et. sp. nov.; exine smooth, polyplicate, interridge distance 4 microns on an average; nonaperturate; 47×31 microns; oblique compressions of pollen grains of *Pistia* are difficult to distinguish from those of *M. eospathiphyllum;* Berry has described fossil leaves of *Pistia* from the Wilcox and Claiborne Formations; some of the fossil pollen recorded in the previous literature as *Ephedra* apparently belong to *Pistia*, and possibly also to *Spathiphyllum* of the *Monsteroideae;* holotype.

„ 12 : *Tetracolporipites* sp.; polar compression; furrows very short; exine rather thin, almost smooth; diameter 11 microns.

„ 13 : *Tetracolpopites* sp.; polar compression; exine thick, finely reticulate, comparatively coarsely reticulate near the equatorial region; diameter 30 microns; seems to be related pollenmorphologically to the *Oleaceae.*

„ 14 : *Triporipites* sp.; polar compression; exine moderately thick, seemingly smooth; exine slightly raised over pore margins; diameter 25 microns.

„ 15 : *Nonaperturipites* sp.; polar compression; exine thin, smooth; l.d. 18 microns; affinity with *Coprosma* (*Rubiaceae*) suspected.

„ 16 : *Nonaperturipites* sp.; exine thick, tuberculate; diameter 21 microns; has pollenmorphologic similarity with *Apama corymbosa* (*Aristolochiaceae*); *Artistolochiaceae* occur in Assam at the present day.

„ 17 : *Tricolporipites* sp.; polar compression; exine very thin, faintly granular; diameter 15 microns.

„ 18 : *Tricolpopites aquifoliaceaeformis* sp. nov.; equatorial compression; exine moderately thick, with minute rods; three furrows; l.d. 21 microns; fossil pollen of *Ilex* are known from Lower Miocene of the Mediterranean region; *Aquifoliaceae* occur abundantly in the Assam forests at the present day; this fossil species is very common in the Lower-Middle Eocene freshwater sediments of the foreland shelf of the Garo, Khasi, Jaintia Hills; holotype.

Figure 19 : *Pentacolpopites* sp. A; polar compression; exine moderately thick, characteristically reticulate; (? ora 4 microns deep); l.d. 33 microns; probably related to *Nothofagus;* difficult to be certain about the precise generic and specific status of this form without comparison with many Eocene species of *Fagaceae* from New Zealand described by Couper.

„ 20 : *Triporipites* sp.; polar compression; exine thin, very finely granular; pores aspidote; l.d. 30 microns; may be related to the *Ulmaceae.*

„ 21 : *Paleoficus spengleri* sp. nov.; exine thin, faintly granular; two pores, with thickening of the exine round the pores; l.d. 23 microns; has pollenmorphologic similarity with modern *Ficus religiosa* L.; *Artocarpae* is a very old tropical-subtropical subfamily, with Eocene fossil records from many parts of the world; holotype.

„ 22 : *Santalaceaepites religiosus* gen. et. sp. nov.; equatorial compression; exine smooth, moderately thick; longitudinal furrows probably vestigial; transverse furrow-ring 3 microns wide; 25 × 20 microns; agrees with pollen of modern *Exocarpus* (*Santalaceae*) except in measurements; holotype.

PLATE NO. VI.

All figures are photomicrographs of fossil forms from the Tura Formation of the Tura-Dalu Road.

Figure 23 : *Caryophyllaceaepites eocenica* sp. nov.; exine thick, with a coarse rod-layer, giving rise to an apparently coarsely reticulate texture; polyforate, 17 fores can be counted, fores 2 microns across; diameter 34 microns; has pollenmorphologic similarity with the modern species *Alsinodendron viscosum* Sherf (rain forest type), *Cerastium alpinum, Lycnis flos-cuculi, Melandrium rubrum, Sagina intermedia, S. nodoso, Scleranthus perennis, Silne acaulis* etc. of the *Caryophyllaceae; Caryophyllaceae* are generally regarded by botanists to be phylogenetically related to but more evolved than the *Chenopodiaceae* and *Amaranthaceae,* but Eocene occurrences of the *Caryophyllaceae* should also be taken into account in interpreting its phylogeny; modern *Caryophyllaceae* are more common in cooler climates and are known from Assam also; holotype; this species has some pollenmorphologic similarity with *Calystegia sepium* of the *Convolvulaceae* also.

„ 24 : *Grevilloideaepites eocenica* sp. nov.; exine thick, reticulate; long diameter of the body 50 microns and of the flanges 18 microns; ora 9 microns across; fossil leaves of Eocene *Proteaceae* have been described from the Eocene of the southeastern states of North America, from the Upper Eocene to Lower Miocene of southeastern France and Dalmatian Islands of the Adriatic region, and fossil pollen of the *Proteaceae* have been described from the Upper Cretaceous to Oligocene of New Zealand, from the Upper Cretaceous strata of Western Alberta, Canada and from the Lower Eocene lignites from Palana, Rajasthan, India; in the context of these records the surmise of Berry to the effect that the now predominantly antipodean *Proteaceae* was cosmopolitan in the Tertiary Period seems to have been adequately proved; there are some 150 modern species of *Helicia* (*Grevillioideae*) distributed between Australia, New Guinea, Borneo, Java, Sumatra, Thailand, Japan, China, Burma, Lushai Hills in India, Ceylon etc.; holotype.

„ 25 : *Paleoaraliaceaepites indica* gen. et. sp. nov.; equatorial compression; exine thick, reticulate, thicker and minutely plicated in the polar region; tricolporate, with prominent longitudinal furrows, apparently functional; transverse furrow 3 microns wide, continuous across the equatorial region; 29×24 microns; although in most modern species transverse furrows are broken, judging from Selling's illustrations, transverse furrow in *Tetraplasandra kaalac Hillebr.* (*Araliaceae*) seems to be entire; fossil leaves of *Araliaceae* are known from the Eocene sediments of U. S. Gulf Coast, Greenland and Mediterranean region; modern *Araliaceae* occur in the Assam forests; holotype.

Figure 26 : *Palmaepites eocenica* sp. nov.; equatorial compression; exine smooth and rather thin; grain measurements 36×24 microns; sulcus nearly as long as the long diameter of the grain, measuring 28×8 microns; common and characteristic of the Lower-Middle Eocene of the Bengal Basin and Indus Basin; in view of the nature of the associated sediments it may be suspected that this species might have been a salt tolerant type, but it has not been possible to identify this species unquestionably with any natural genera, although it has pollenmorphologic similarities with modern *Jessina bataua* from Brazil and with *Juania australis* from the Juan Fernandez Islands; it is interesting to note in this context that fossil fruits of *Nipa* palm are common in the Eocene of the entire European region, of the Mediterranean region, occur also in the Eocene of U.S. Atlantic coast, and *Nipa* plams have been described from the Eocene intertrappean beds of the Deccan Traps of India; holotype.

" 27 : *Papaveraceaepites thalmanni* sp. nov.; polar compression; exine very thick, reticulate in the equatorial zone, much less so in the polar region; diameter 23 microns; suggestion of 9 colpae; 9 distinct fores, 4 microns across, and located 4 microns from the equatorial margin toward the polar region; has some pollenmorphologic similarity with the modern species of *Fumaria officinalis* and *Sanguinaria canadensis;* botanists regard the *Papaveraceae* to be highly evolved, but the family being characteristically eurypalynous, it is possible that whereas some of the species are more highly evolved, others may be geologically old; in fact occurrences of fossil *Papaveraceae* have been described from the Upper Eocene of Hordle, Hants, England by Chandler; holotype.

" 28 : *Paleosantalaceaepites dinoflagellata* gen. et. sp. nov.; equatorial compression; exine moderately thick, smooth; grain measurements 42×34 microns; longitudinal colpae conspicuous, apparently functional, but do not have pole to pole extension; transverse furrow less prominent but well defined, 3 microns across, having superficial resemblance with the "equatorial band" of the dinoflagellates; genoholotype.

" 29 : Unidentified pollen; exine densely packed with minute papilla; suggestion of one furrow extending pole to pole; affinity unknown; pollenmorphologic similarity. with *Gentianaceae, Aquifoliaceae, Tricolpopites alveolatus* Couper, *Potamogetonaceae, Nymphaeaceae* etc.; 26×21 microns.

" 30 : *Syncolporipites* sp.; polar compression; exine thin, faintly granular; l.d. 23 microns; has pollenmorphologic similarity with the *Gentianaceae.*

" 31 : *Colocasioideaepites kingstoni* sp. nov.; exine thick, densely packed with spines, of the order of 2 microns long, 1 micron across at the base; diameter 20 microns (exclusive of spines); nonaperturate; the Tura Formation and coeval freshwater sediments of the Sylhet Limestone Formation contain varied and abundant pollen remains of the *Araceae;* this species has general pollenmorphologic similarity with modern *Remusatia vivipara, Colocasia antiquorum* Schott etc.; Wodehouse has described *Peltandripites davisi* from the Green River Formation; holotype.

" 32 : *Nymphaeaceaepites asteri* sp. nov.; exine thick, echinate, with comparatively few robust spines measuring 7 microns in length and 3 microns at the base; l.d. 27 microns; germinating apparatus not distinct; it is known that *Nymphaeaceae* and *Araceae* are both geologically old, have an "amphibian" character, and are characterised by strong pollenmorphologic similarities particularly common with ancient fossil genera; holotype.

" 33 : *Wadiapites caryophylla var. a* ven. et. sp. nov.; exine moderately thick, finely reticulate; grain diameter 33 microns; six fores equatorially located, each 7 microns across; holotype.

Figure 34 : *Lemnaceaepites austini* sp. nov.; exine thin, smooth beset with sparsely spaced slender spines, measuring 2 microns in length; grain diameter 24 microns; nonaperturate to all appearances; *Lemnaceae* are known to be phylogenetically related to the *Araceae;* holotype.

„ 35 : *Coniferaepites* sp.; proximal compression; bladders coarsely reticulate; measurements 66×44 microns inclusive of bladders; tubecell 38×31 microns; although very well-preserved, no generic or specific diagnosis has been attempted because of taxonomic complexities associated with the detatched sporomorphs of the *Coniferae,* and because of difficulty of comparative studies with previously described forms; conifer pollen occur very sparsely in the Tura Formation teeming with millions of other types of fossil pollen; this appears very significant in view of the fact that in the Middle-Upper Miocene sediments of the Garo Hills and of the other parts of the folded belt there is a fair abundance of conifer pollen (usually associated with abundant spores of *Aneimia* or *Ceratopteris*); further, conifer pollen constitute a dominant element in the sporepollen assemblages of Pliocene age of the folded belt; therefore, the abundance of conifer pollen can be correlated in the Bengal Basin, as in the Mediterranean region, with the degree of uplift of the mobile belt and/or of portions of the foreland shield area.

PLATE NO. VII.

All figures are photomicrographs of fossil forms from the Tura Formation of the Tura-Dalu Road section.

Figure 36 : *Nonaperturipites thiergarti* sp. nov.; exine thick, densely packed with large tubercles on short rods, tubercles uniformly large measuring 3.5 microns; diameter 49 microns; precise affinity unknown, but believed to be related pollenmorphologically to the families *Nymphaeaceae, Gentianaceae, Hydrocharitaceae* etc.; additional clues to the precise natural affinities of the genus may be forthcoming when the pollenmorphologic characteristics of all the species of some 30 known families of angiosperms of India having aquatic adaptations happen to be worked out; this species is common and characteristic of freshwater Lower-Middle Eocene sediments of the foreland shelf of the Bengal Basin; holotype.

„ 37 : *Colacasioideaepites nymphaeaceaeformis var. densa* sp. nov. var. nov.; exine moderately thick, faintly granular, with widely spaced spines, spines 8-10 microns, very slightly swollen at the base; diameter of the grain exclusive of spines 53 microns; nonaperturate; pollenmorphologic distinction between the *Nymphaeaceae* and *Araceae* is quite difficult and such pollen might have really belonged to then existing but now extinct genera and species intermediate between the *Nymphaeaceae* and *Araceae;* the species in question had been referred to the *Araceae* on the basis of its presumed phylogenetic relationship with the abundant and diverse pollen species of the *Araceae* known from Paleocene freshwater deposits of the Bengal Basin (unpublished work of the writer); has strong pallenmorphologic similarity with the living species *Alocasia indica* of the *Araceae.*

„ 38 : *Nonaperturipites berryi* sp. nov.; exine very thick, with closely packed coarse warts of nearly uniform dimensions althrough; diameter 72 microns; a characteristic, though comparatively rare, species from the Lower-Middle Eocene freshwater deposits of the Bengal Basin; the precise natural affinities of the species could not be worked out; it has general morphologic similarity with the pollen of *Alangiaceae* (tricolporate), *Rusbyanthus cinchonifolius* of the *Gentianaceae* (presumably tricolporate, smaller), *Lilioideae* (sulcate/operculisulcate/aperturate), nonaperturate *Linaceae, Phaleria capitata* of the *Thymelaeaceae* (polyforate), proximal compression of *Nymphaea candida* (smaller, with smaller warts, and operculisulcate); an affinity of this species with the *Nymphaeaceae* may be conjectured; for instance the proximal compression of a pollen of the dimensions of *Victoria cruziana* with tubercles coarser than that of *Nymphaea candida* may be conceived to have the appearance of this pollen species; holotype.

Figure 39 : *Tetracolporipites* sp.; exine consists of thickened lobes and thinner areas in the colpal zone, thickened lobes more coarsely reticulate than the thinner areas; furrows and pore located in the middle of the thinner areas, diameter of the whole grain 36 microns; thickened lobes 20 microns wide at the equator; furrows 13 microns long; have pollenmorphologic similarity with modern *Guilandina* of the *Caesalpinoideae* and *Platonia insignis* of the *Guttiferae.*

" 40 : *Nonaperturipites browni* sp. nov.; exine thick, coarsely reticulate, with rod-like projections that have rounded tips; diameter 42 microns; pollenmorphologic similarity with the *Aponogetonaceae,* with *Aleurites moluccana* of the *Euphorbiaceae,* with *Aristolochiaceae,* with some species of the *Nymphaeaceae* etc.; holotype.

" 41 : *Hystrichospherid,* wall very thin; diameter of the body exclusive of flange 51 microns; flange partly intact, 13 microns wide; numerous slender spines, nonanastomosing, 9-10 microns long; hystrichospherids seem to occur in open marine as well as in brackish environments; from other lines of evidences, there is no doubt that this hystrichospherid is from a brackish water life habitat.

PLATE NO. VIII.

All figures are photomicrographs of fossil forms from the Tura Formation of the Tura-Dalu Road section.

Figure 42 : *Coniferaepites* sp.; measurements inclusive of bladders 108 × 80 microns; bladders thick, with reticulate ornamentation, bladders 80 × 51 microns, tube cell slightly longer than the bladder, faintly reticulate; proportion of bladders and tube cell, and texture of the bladders and of the tube cell, are suggestive of a natural affinity of this species with *Picea*; as mentioned elsewhere conifer pollen are sparsely represented in this stratigraphic level.

" 43 : *Colocasioideaepites brevispina* sp. nov.; exine comparatively thin, almost smooth, spines 6-7 microns long, characteristically bulbose at the base, with sharply pointed apex; measurements of the whole grain 45 × 32 microns; nonaperturate; this species is widely distributed in the Lower-Middle Eocene freshwater sediments of the entire foreland shelf of the Bengal Basin as also in the marginal carbonaceous developments of the same age of the Indus Basin; genoholotype; (thin nature of the exine accounts for its folding often simulating germinal apparatus of various kinds).

" 44 : *Tricolpopites proboscidea* sp. nov.; polar compression, exine thick, uniformly reticulate; tricolpate; has some pollenmorphologic similarity with the *Plumbaginaceae, Labiatae, Gunneraceae, Oleaceae* etc.; holotype.

" 45 : *Hystrichospherid;* wall thin; both spines and processes occur, though comparatively few; diameter of the specimen exclusive of spines and processes 45 microns; spines 8-9 microns long; flange seemingly differentiated into a band.

" 46 : *Colocasioideaepites nymphaeaceaeformis* sp. nov.; faintly granular; spines 8-9 microns long, slightly swollen at the base; l.d. 55 microns; nonaperturate; differs from *C. nymphaeaceaeformis var. densa* in having decidedly lesser number of spines; differs from *C. brevispina* in having spines which are not bulbose basally; there seems to have been several closely related species of the *Araceae* flourishing in the marshes of the coal basins of the Tura Formation; holotype.

" 47 : *Hystrichospherid;* wall thin; spines nonanastomosing; diameter 47 microns.

PLATE NO. IX.

All figures are photomicrographs of fossil forms from the Tura Formation of the Tura-Dalu Road section.

Figure 48 : Unidentified form; wall thin; diameter of the body exclusive of spine 66 microns; spines about 30 microns long.

Figure 49 : *Nonaperturipites chandleri* sp. nov.; exine thick, with rods that are not rounded (as against those in *Nonaperturipites browni*); also suggestion of circular opercular attachment very near the equator; diameter 56 microns; apparently related to the *Nymphaeaceae* phylogenetically; holotype.

„ 50 : *Erdtmanipites terminaliaformis* gen. et. sp. nov.; polar compression, exine almost smooth, rather thin; hexacolpate; furrows 5 microns deep, 10-12 microns wide at the equator; has pollenmorphologic similarity with modern species of *Terminalia;* fossil leaves of *Terminalia* are known from the Eocene of the U. S. Gulf Coastal basin; from the Eocene of the Paris Basin, and from the Eocene-Pliocene of the Mediterranean regions; seeds consist of nuts embedded in a tough rind, well adapted for dispersal by sea currents; believed by botanists to be a native of Malaya, Andaman Group of Islands etc.; holotype.

„ 51 : *Paleocaesalpiniaceaepites eocenica* gen. et. sp. nov.; polar compression; diameter 40 microns; exine is differentiated into three lobes and three interlobes; lobes thickened, coarsely reticulate, 24 microns wide at the equator; interlobe areas nearly half as wide as the lobes; closely related to *Mesoneuron kauaiensis* (Mann) Hillebr., *Caesalpinia bonducella* Flem., *C. sappan* etc., although this fossil species is devoid of pores, which in addition to furrows characterise the modern species; fossil leaves of *Caesalpinia* have been recorded from the Eocene of U. S. Gulf Coastal region, Oligocene of France, and Tertiary of Bolivia and Ecuador; Berry notes that *C. bonducella* is cosmopolitan, that its seeds float uninjured in sea for months, and that instances are known where the seeds, that have been successfully used to raise plants, have apparently floated all the way from West Indies to Irish and Scandinavian coasts; holotype.

„ 52 : *Colocasioideaepites kamrupensis* sp. nov.; exine thick, very faintly granular; diameter 54 × 35 microns; spines characteristically elongate, 6-8 microns long, with pointed tips; holotype.

„ 53 : *Leiotriletes virkkii* sp. nov.; proximal compression; exine moderately thick, very finely though distinctly granular; l.d. 42 microns; length of the letes 13 microns; shape rounded triangular; transverse folds at the tip of the rays common; one of the most common pteridophytic spores occurring in the Lower-Middle Eocene freshwater sediments of the Bengal Basin; may be related to *Polypodiaceae, Gleicheniaceae* etc.; holotype.

„ 54 : *Polypodiceaesporites stoliczkana* sp. nov.; 43 × 23 microns; exine moderately thick; spore body sheathed completely in a perisporal membrane; exospore membrane coarsely reticulate; holotype.

PLATE NO. X

All figures are photomicrographs of fossil sporepollen from the second clastic interbed, shales of the middle member of the Sylhet Limestone Formation, of the Um Sohryngkew River Section in the vicinity of Therria Ghat. Fox suggested an Eocene age of the Tura Formation, and A. M. N. Ghosh tentatively correlated it with the lower and middle parts of the Sylhet Limestone Formation of the Therria Ghat Section. Precise paleontological evidence is adduced in this and following plates in support of a Lower-Middle Eocene age of the fossil sporepollen assemblages from the type Tura Formation illustrated in the preceeding plates.

Figure 1 : *Oldhamisporites* sp.; oblique compression; exine thick, smooth; l.d. 62 microns; has sporemorphologic similarity with the *Cyatheaceae*; differs from *O. cyatheaceaeformis* in having a smooth exine; spores of the *Cyatheaceae* are known from Aptian of the Russian platform and leaves of *Protocyatheaceae* are known from the intertrappean beds of the Rajmahal Group (possible Lower Cretaceous) and from the Uttattur plant beds (possible upper part of Lower Cretaceous); since the germinal apparatus has not been studied, no specific designation of this form has been attempted; occurrence rare.

„ 2 : *Leiotriletes* sp.; proximal compression; exine moderately thick; smooth; l.d.

29 microns; moderately common in the Lower-Middle Eocene freshwater sediments of the Bengal Basin; because of the generalised morphology of the form, it has not been possible to determine its natural affinities.

Figure 3 : *Tricolpopites* sp.; equatorial compression; exine comparatively thick, with minute papilla; l.d. 23 microns; this and related species are common in the freshwater Lower-Midddle Eocene sediments of the Bengal Basin; it has not been possible to determine their natural affinities without making a comparative pollenmorphologic study with their related modern pollen counterparts.

„ 4 : *Medlicottipites utriculariaformis* gen. et. sp. nov.; polar compression; exine smooth, with nine colpae, exine of the intercolpal region has comparable thickness as that of the polar region; diameter of the whole grain 15 microns; furrow 2-3 microns deep; has strong pollenmorphologic similarity with the modern pollen of *Utricularia flexuosa* Vahl. (*Lentibulariaceae*), common planktons of the freshwater tanks of Bengal and of other parts of India; it is possible that some species of *Utricularia* and related forms have maintained an aquatic-marshy habitat ever since the Eocene times; holotype.

„ 5 : *Tricolporipites* sp.; polar compression; exine smooth, comparatively thin; furrows short, narrow; natural family affinity difficult to decide in view of the comparable pollenmorphology characterising several families of dicotyledons; diameter 18 microns.

„ 6 : *Umbelliferaepites paleoaromata* sp. nov.; grain slightly pinched at the equator along the transverse furrow, a characteristic feature of the pollenmorphology of the family; longitudinal furrows are not conspicuous, though present; exine moderately thick, nearly smooth; polar diameter 18 microns; previous records of fossilised remains of the *Umbelliferae* are not known to the writer, but the pollenmorphology of the species is diagnostic of this predominantly herbaceous family; holotype.

„ 7 : *Laevigato-sporites traversei* sp. nov.; perisporal membrane very thin, finely reticulate, with large warts; l.d. 40 microns; bilaterally symmetrical spores with perisporal membrane are most common in the modern *Polypodiaceae* family, although a comparable pattern of sculpturing of the membrane has not been observed in the published literature; precise family affinity is uncertain, because a generally comparable sporemorphology does occur and may conceivably occur in a number of families, such as, the *Hymenophyllaceae, Dicksoniaceae* etc., other than in the *Polypodiaceae*; holotype.

„ 8 : *Stenozonotriletes kaufmanni* sp. nov.; proximal compression; l.d. 39 microns; flange 2 microns across; exine thick; central body reticulate; minute papillae on the flange; trilete rays extend to the periphery of the central body; has strong sporemorphologic similarity with the *Cyatheaceae,* with forms, such as, *C. brunoniana,* but precise family affinity unknown; holotype.

„ 9 : *Cushmanipites chaunochitoniformis* gen. et. sp. nov.; polar compression; l.d. 33 microns; "sexine"—"nexine" differentiation sharp; "sexine" densely granular; aperture apparently syncolpate; has pollenmorphologic similarity with modern *Chaunochiton kappleri* and *Schoepfia chrysophylloides* of the *Olacaceae*; known from the modern Assam forests are *Olax acuminata* Wall., *O. nana* Wall., *Erythropalum vagum* Mast., *E. scandens* Bl., *Schoepfia fragrans* Wall., *S. acuminata* Wall., *Lepionurus sylvestris* Bl., and *Anaclosa ilicoides* Mast.; known from the modern Sunderban mangrove forests in the southern part of the Bengal Delta is *Olax scandens* Roxb.; pollen of the *Anaclosa* type has been described from the Upper Tertiary of Nigeria by Kuyl et al; pollen of the *Anaclosa* type are quite common in the freshwater Lower-Middle Eocene sediments of the Bengal Basin; holotype.

„ 10 : *Nonaperturipites* sp.; exine comparatively thin, smooth; diameter 16 microns; natural affinity unknown; one of the families with which an affinity may be suspected is the *Euphorbiaceae.*

Figure 11 : *Triporipites betulaceaeformis* sp. nov.; polar compression; exine smooth; sexine thicker than nexine; pores aspidote; l.d. 23 microns; macroscopic remains of the *Betulaceae* are known from the Upper Cretaceous of North America; Wilson has described *Betula claripites* Wodehouse (Green River Formation) also from the Paleocene coal of the Fort Union Formation of Montana; Russian workers have described fossil pollen of *Betula* from the Albian-Cenomanian; holotype.

,, 12 : *Tricolporipites jacobi* sp. nov.; polar compression; exine moderately thick, nearly smooth; l.d. 20 microns; furrows very short; pronounced thickening of the exine around the germ pores; probably related to the *Tiliaceae*; holotype.

,, 13 : *Tricolporipites atkinsoni* sp. nov.; equatorial compression; l.d. 17 microns; exine thin, smooth; natural affinity unknown; quite common in the freshwater Lower-Middle Eocene sediments of the Bengal Basin; thin nature of the exine apparently accounts for generally irregularly twisted outline of this species; the species illustrated in figure 5 of this plate may represent the polar compression corresponding to the equatorial compression of fig. 13; holotype.

,, 14 : *Tricolporipites* sp.; polar compression; l.d. 20 microns; exine very thin and faintly granular; slight thickening around the germ pores; may be phylogenetically related either to the *Tiliaceae* or to the *Betulaceae*; distinction between pore/furrow difficult.

,, 15 : *Santalaceaepites religiosus* sp. nov.; equatorial compression; l.d. 18 microns; longitudinal furrows apparently vestigial; transverse furrow ring 2 microns across; exine moderately thick, smooth; holotype described from the type Tura Formation in this paper.

,, 16 : *Oldhamisporites cyatheaceaeformis* gen. et. sp. nov.; proximal compression; exine thick, slightly granular and with very minute spinose projections; l.d. 62 microns; trilete rays rather short; has strong sporemorphologic affinities with the modern *Cyatheaceae*; occurrence relatively rare in the Lower-Middle Eocene freshwater sediments of the Bengal Basin; holotype.

,, 17 : *Tricolporipites jerdoni* sp. nov.; polar compression; l.d. 26 microns; exine rather thick, slightly granular; furrows very shallow but wide; pronounced collar-like thickening of the exine around the germ pores; probably related to the *Tiliaceae*; holotype.

,, 18 : *Triporipites* sp.; polar compression; exine thick, slightly granular; l.d. 23 microns; pores at the protruding angles; no suggestion of thickening around the pores; may be related to the *Ulmaceae, Casuarinaceae, Tiliaceae* etc.; pollen grains with identical pollenmorphology occur also in the type Tura Formation.

PLATE NO. XI.

All figures are photomicrographs of fossil sporepollen from the middle member of the Sylhet Limestone Formation of the Um Sohryngkew River section north of Therria Ghat.

Figure 19 : *Polyforipites hemchandrai* sp. nov.; exine very thick, apparently smooth; l.d. 61 microns; fore margin with collar, some fores as large as 8 microns across; spines 7 microns in length and 4 microns wide at the base on an average; natural affinity difficult to decide; most obvious pollenmorphologic similarity is with some of the species of *Convolvulaceae* and *Malvaceae*; however, Erdtman reports oligoforate condition in the *Araceae* also; a satisfactory resolution of the problem of the phylogenetic affinity of this species seems possible when a monographic study of the pollenmorphology of the *Araceae* family is made and when additional clues as to the parent plant from associated macrofossil remains, if any, are available; holotype.

Figure 20 : *Araceaepitels micrograntulata* sp. nov.; exine comparatively thin, distinctly but very finely granular; l.d. 56 microns; spines sparse, length of spines on an average 10-12 microns; nonaperturate; absence of germinating apparatus suggests a natural affinity with the *Araceae,* rather than with the *Nymphaeaceae* or *Palmae*; holotype.

„ 21 : *Nonaperturipites* sp.; exine nearly smooth; comparatively thin; with very short, sparse spines; l.d. 26 microns; pollenmorphologic affinity with the *Lemnaceae, Pandanaceae, Salix* of the *Liliaceae* etc.

„ 22 : *Nonaperturipites evansi* sp. nov.; exine thick, with coarse warty excrescences; l.d. 32 microns; nonaperturate; strong pollenmorphologic similarity with the modern species *Phaleria capitata* of the *Thymelaeaceae*; Erdtman notes a polyforate condition in this Recent species but mentions that foramina are not distinct; *N. evansi* has alternative pollenmorphologic similarity with the *Aristolochiaceae, Linaceae, Euphorbiaceae* etc.; *N. evansi* occurs comparatively rarely but is an important index fossil for the freshwater Lower-Middle Eocene sediments of the Bengal Basin; holotype.

„ 23 : *Nonaperturipites potamogetonaceaeformis* sp. nov.; exine thick, with thickly crowded moderately coarse and fine pila; l.d. 53 microns; has strong pollenmorphologic similarity with some species of the *Potamogetonaceae,* also with *Liliaceae,* primitive *Nymphaeaceae, Amaryllidaceae, Pontederiaceae, Araceae, Gentianaceae* etc.; Rao and Vimal have described fossil (?) *Potamogeton* pollen from the Eocene lignites of Palana and Dandot of the Indus Basin and from the (?) Miocene Cuddalore Lignites of the Coromandel coastal basin; fossil records of the *Potamogetonaceae* are known from the Eocene Green River, Wilcox and Jackson Formations and from the Miocene Latah and Florissant Formations of North America; holotype.

„ 24 : *Araceaepites nagappai* sp. nov.; exine comparatively thick, slightly granular, spines 5-7 microns long; l.d. 36 microns; nonaperturate; it is believed that many allied species of the *Araceae* used to flourish in large numbers in the basin margin areas and in the freshwater depositional basin of the extreme updip areas of the foreland shelf of the Bengal Basin in the Lower-Middle Eocene times; holotype.

„ 25 : *Paleocaesalpiniaceaepites eocenica* gen. et. sp. nov.; polar compression; a collapsed grain; l.d. 36 microns; holotype described from the type Tura Formation in a previous section of this paper.

„ 26 : Unidentified pteridophytic spore; oblique compression; l.d. 36 microns; exine thick and uniformly reticulate; differs from *Stenozonotriletes kaufmanni* in not having a peripheral flange.

„ 27 : *Colocasioideaepites benstonei* sp. nov.; exine thick, smooth as far as can be judged, densely packed with spines 3-4 microns long, with comparatively broad base and pointed apex; l.d. 39 microns; nonaperturate; holotype.

„ 28 : *Nonaperturipites* sp.; l.d. 43 microns; exine comparatively thin, slightly granular; moderately coarse pila are much less numerous than in *Nonaperturipites potamogetonaceaeformis,* although seemingly related to the latter species pollenmorphologically, and possibly phylogenetically also.

„ 29 : *Nonaperturipites* sp.; l.d. 51 microns; exine thick, with moderately coarse pila; differs from *Nonaperturipites potamogetonaceaeformis* in having less numerous pila and in having pila characteristically with a sharply constricted neck; apparently related phylogenetically to the *Potamogetonaceae, Liliaceae,* etc.

PLATE NO. XII.

All figures are photomicrographs of fossil pollen from the shales of the second clastic interbed of the Sylhet Limestone Formation from the Um Sohryngkew River section in the vicinity of Therria Ghat.

Figure 30 : *Araceaepites wodehousei* sp. nov.; exine rather thick, distinctly though rather finely reticulate; spines 9-11 microns long; l.d. 40 microns; in none of the modern species of the *Araceae* examined by the writer does reticulate exine and spines occur together; for instance, in the *Pothoideae, Monsteroideae* and *Calloideae* reticulate exine is characteristic of some species; on the other hand nonaperturate spinose pollen occur in some of the species of the *Colocasioideae* and *Aroideae*; in the Paleocene-Eocene freshwater sediments of the Bengal Basin all three types of *Araceae* pollen occur, with reticulate exine, with spinose exine, and with spinose as well as reticulate exine; holotype.

„ 31 : *Gentianaceaeformis indica* sp. nov.; l.d. 50 microns; exine thick, with closely packed pila, pila rather fine, with not much difference between the width of the rods and heads of the pila; suggestion of two furrows; has quite strong pollenmorphologic similarity with the pollen of the modern species *Rusbyanthus cinchonifolius* of the *"Gentianoideae-Rusbyantheae"* of Erdtman; there are a large number of allied pollen types associated, having varying degrees of pollenmorphologic similarity, that seem to belong to plants inhabiting dominantly aquatic-marshy habitats; holotype.

„ 32 : *Colocasioideaepites sellingi* sp. nov.; l.d. 47 microns; exine comparatively thick, very slightly granular; spines short, broad-based, but not bulbose basally; spines 3-4 microns long; nonaperturate; differs from somewhat similar *C. nymphaeaceaeformis* in having decidedly shorter spines, and from *C. benstonei* in having less numerous spines and in also having a granular exine; holotype.

„ 33 : *Colocasioideaepites brevispina* sp. nov.; exine rather thin, smooth for all practical purposes (up to x 600 diameters); l.d. 40 microns; spines bulbose basally; holotype described from the type Tura Formation in a preceeding section of this paper; this species is an index fossil for the Lower-Middle Eocene freshwater sediments of the Bengal Basin, much in the same manner as some of the index species of larger foraminifera from the coeval marine shelf sediments.

„ 34 : *Colocasioideaepites simsangensis* sp. nov.; l.d. 44 microns; exine thin, smooth for all practical purposes, spines 5-6 microns long, characteristically tapering; nonaperturate; differs from somewhat similar *C. kamrupensis* in having decidedly thinner, smooth exine and in having tapering (not more or less parallel-sided) spines; differs from *C. sellingi* in having smooth thinner exine; differs from *C. nymphaeaceaeformis* in having a smooth thinner exine and shorter spines; differs from *C. brevispina* in having uniformly tapering and not basally bulbose spines; holotype.

„ 35 : *Nymphaeaceaepites wilsoni* sp. nov.; l.d. 41 microns; exine thick with densely packed minute pila; strong suggestion of an operculum; pollenmorphologically quite similar to the modern species *Nymphaea alba;* holotype.

„ 36 : *Colocasioideaepites* (?) *kamrupensis*; exine moderately thick, slightly granular, spines 3-5 long and slender; l.d. 42 microns; nonaperturate; spines shorter than in *C. kamrupensis* but tend to be more or less parallel-sided.

„ 37 : *Triporipites* sp.; polar compression; exine moderately thick, smooth; l.d. 14 microns; natural affinity not known.

„ 38 : *Paleorubiaceaepites psychotria* gen. et. sp. nov.; polar compression; l.d. 45 microns; exine comparatively thin, characteristically irregularly reticulate, "lumina" varying widely in shape and size, largest being 8 microns across; in polar compression acolporate; but on turning the grains their tetracolpate nature is clearly seen; has strong pollenmorphologic similarity with modern swamp forest, tree/shrub species *Psychotria grandiflora* Mann. of Hawaii; it appears intriguing that fossil leaves of *Psychotria* should be known from the Eocene of the U. S. Gulf Coast and from the Early Tertiary rocks of Chile; holotype.

Figure 39 : *Triporipites* sp.; polar compression; l.d 9 microns; exine very thin, very slightly granular; precise family affinity unknown; but the small dimensions and general pollenmorphology suggest a possible relationship with the *Moraceae.*

PLATE NO. XIII.

All figures, except fig. 49, are photomicrographs of fossil sporepollen from the second clastic interbed of the Sylhet Limestone Formation from the Um Sohryngkew River section in the vicinity of Therria Ghat. Figure 49 is from the type Tura Formation.

Figure 40 : Fungal spore; length of the grain 56 microns; sporecoat thick, septa very thick; fungal spores of this type and of various other types occur quite commonly in this horizon.

,, 41 : *Potamogetonaceaepites pramathi* sp. nov.; exine moderately thick, uniformly reticulate, though comparatively finely; nonaperturate; l.d. 44 microns; pollenmorphology more or less identical with that of the modern partly submerged and partly floating aquatic herb *Potamogeton crispus* of Indian freshwater lakes and ponds; it should be mentioned that in the Recent pollen preparations of *P. crispus* exine foldings often gives an impression of a colpate or sulcate nature of the pollen of this species, but "unmutilated" grains are as a rule nonaperturate; holotype.

,, 42-43 : *Araceaepites conditi* sp. nov.; l.d. 51 and 54 microns respectively; exine apparently smooth; apparently with an equatorial furrow dividing the grains into two equal halves along the hinged equatorial furrow; pollenmorphologically related to the *Araceae,* probably with the *Monsteroideae,* possibly with the forms like *Afroraphidophora africana* illustrated by Erdtman; pollen with comparable morphologic structure have been described by Kuyl et al from the Paleocene of Columbia, S. America and from the Eocene and Middle Tertiary of Nigeria; holotype described in an unpublished paper of the writer.

,, 44 : (?) *Paleocaesalpiniaceaepites eocenica*; l.d. 34 microns; seems to be an equatorial compression of *P. eocenica* or of a related species in which the interlobe areas are compressed or are actually narrower; has some pollenmorphologic similarity with the modern species of *Avicennia* of the *Verbenaceae* (*Avicenniaceae*), *Sonneratia* (*Lythraceae/Sonneratiaceae*), *Excoecaria agallocha* (*Euphorbiaceae*), *Cruciferae, Ranunculaceae* etc.

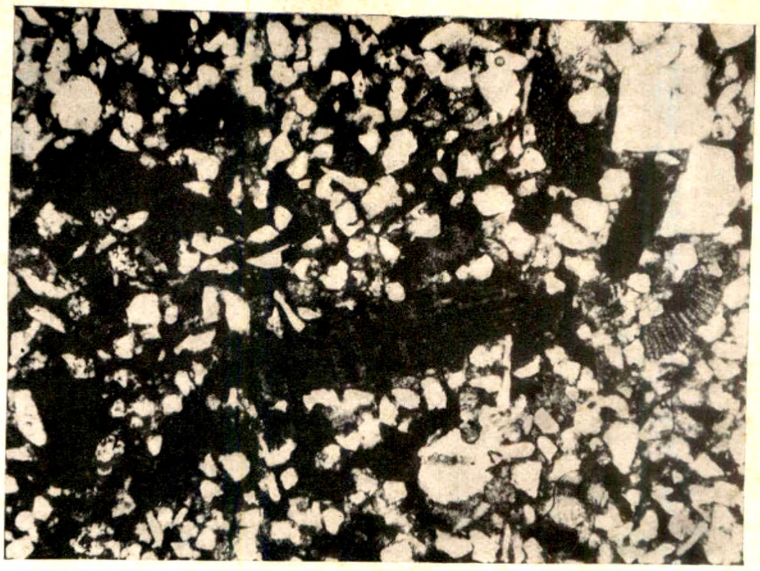
,, 45 : *Tricolpopites foxi* sp. nov.; l.d. 42 microns; exine moderately thick, reticulate; furrows deep, extending to the subpolar region; morphology characteristic so as to be easily identifiable; precise natural affinities could not be determined but has strong pollenmorphologic similarity with the modern species *Dicentra spectabilis* of the *Fumarioideae* of the *Papaveraceae,* and with *Phyllostegia glabra* Benth. of the *Labiatae;* holotype.

,, 46 : *Pentacolpopites* sp. A; l.d. 36 microns; identical with the species described in fig. 19 of pl. 5 of this paper (type Tura Formation).

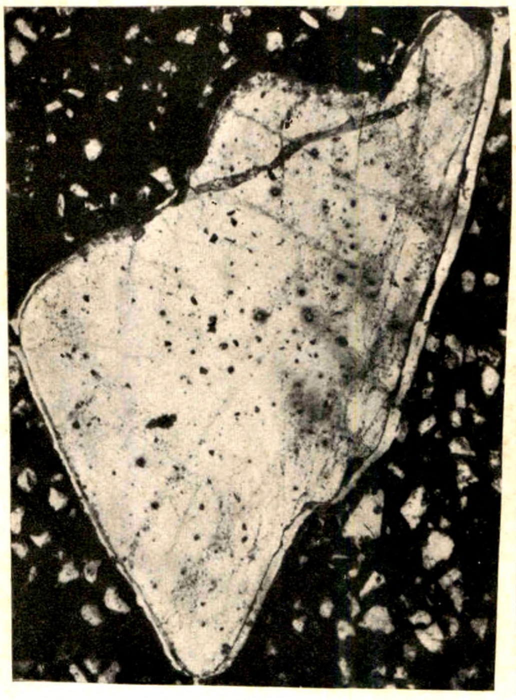
,, 47 : *Pentacolpopites* sp. B; l.d. 34 microns; more or less identical with the species from the type Tura Formation illustrated in fig. 6, pl. 5 of this paper.

,, 48 : (?) *Hexacolpopites* sp.; equatorial compression; exine moderately thick, reticulate; l.d. 36 microns; natural affinity unknown.

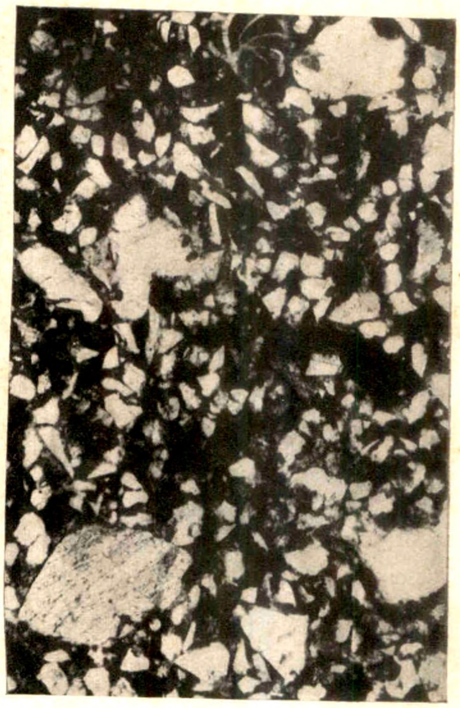
,, 49 : *Knoxipites nymphaeaceaeformis* gen. et. sp. nov.; diameter 42 microns; exine thick, distinctly striate with rod layers; apparently with an operculum; exine sculpture similar to that of *Cabomba aquatica* of the *Nymphaeaceae;* has some pollenmorphologic similarity with "nonporal views" of *Isoglossa lactea* of the *Acanthaceae,* with that of the *Dipterocarpoidae,* with the *Potamogetonaceae* etc.; holotype; this specimen is from the type Tura Formation.



1

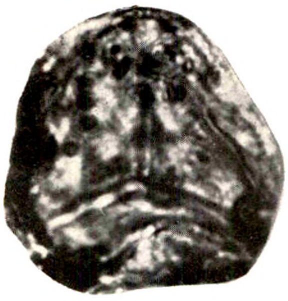


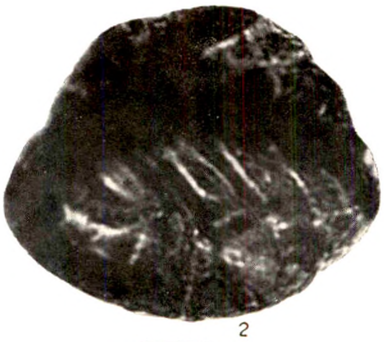
2

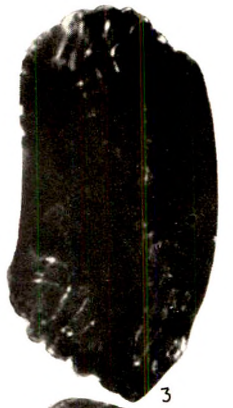


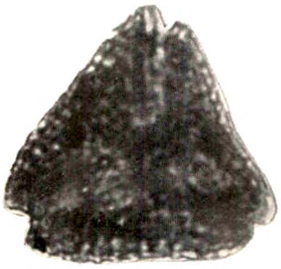
3

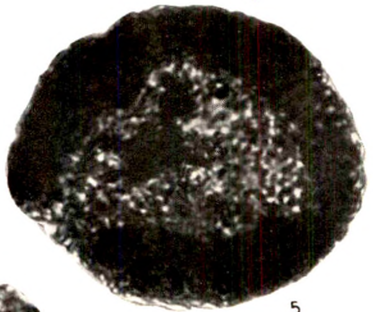
PLATE I

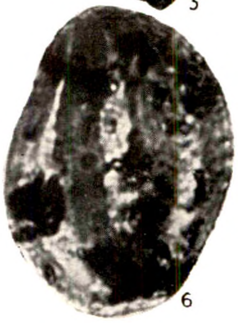

1

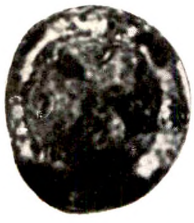

2

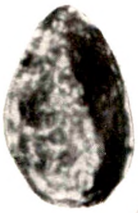

3

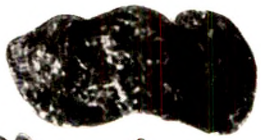

4

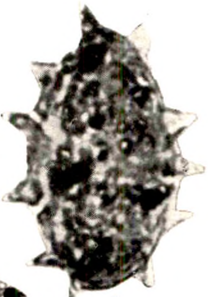

5

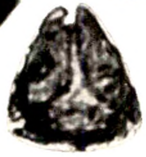

6

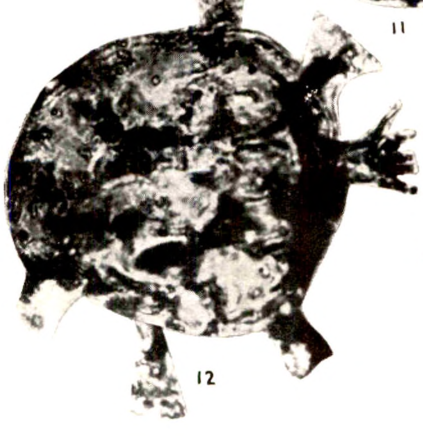

8


9


10


7


11


12

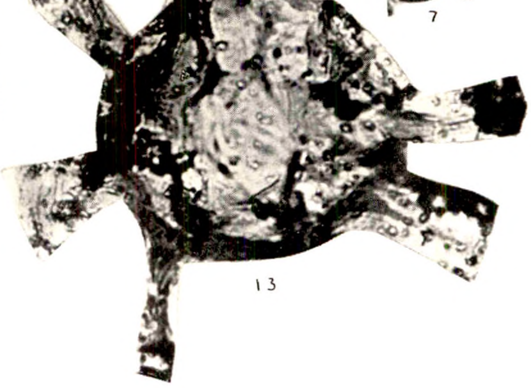
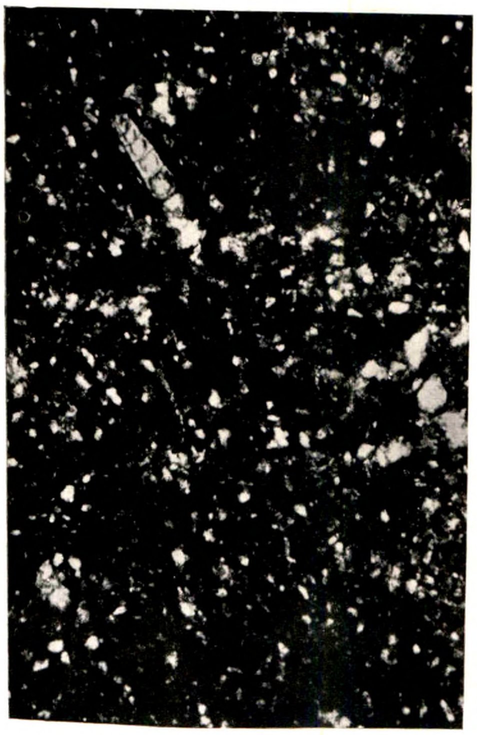
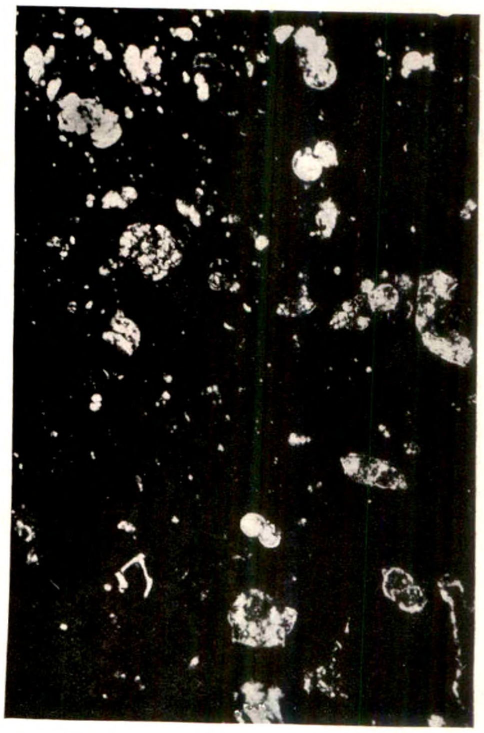

13

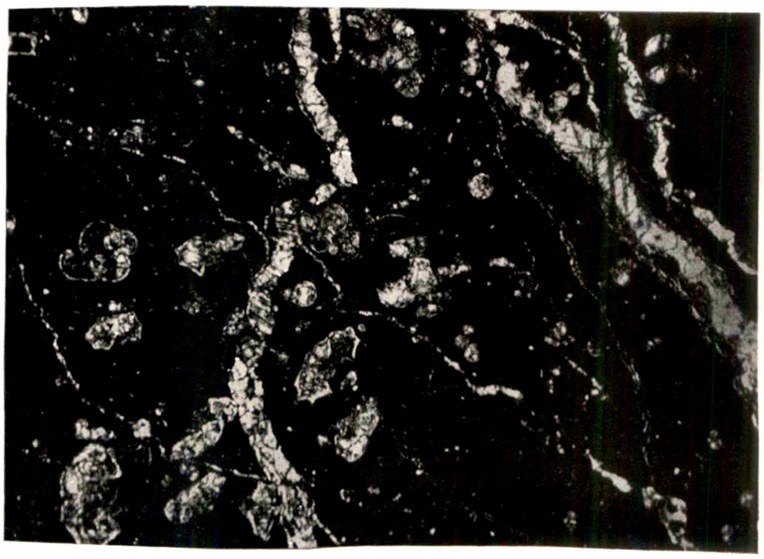
PLATE II



1

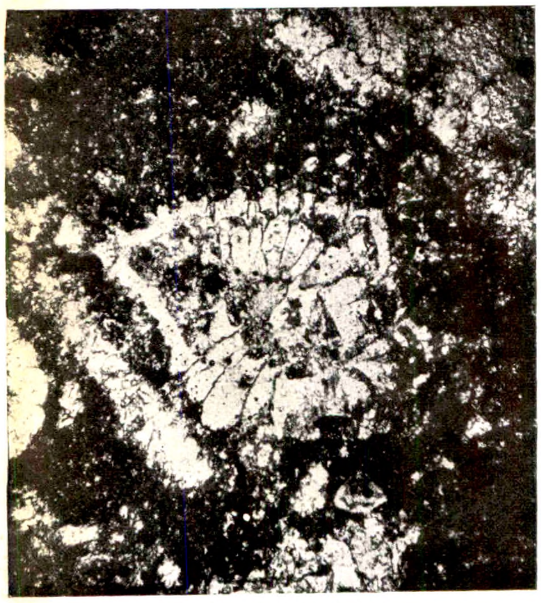


2

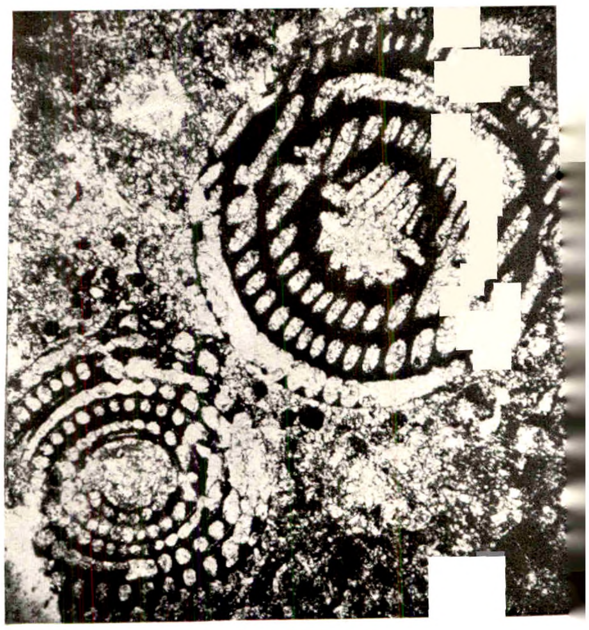


3

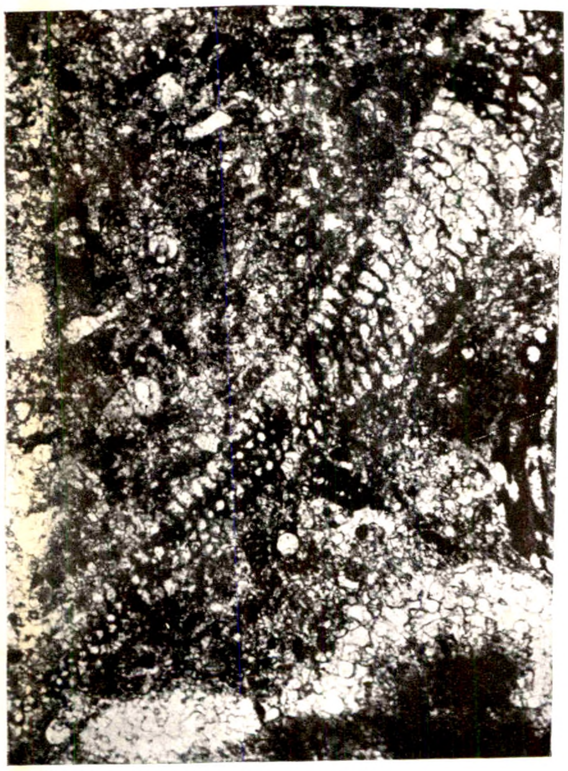
PLATE III



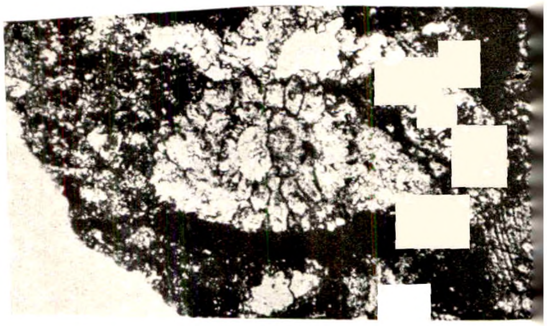
1



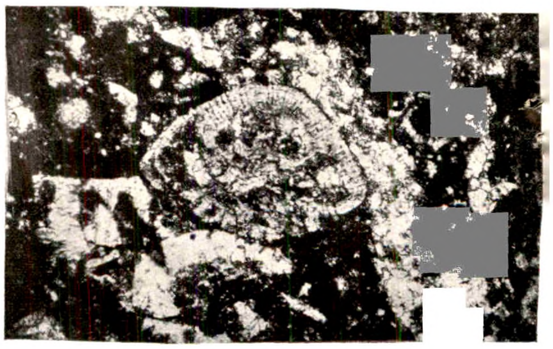
2



3



4



5

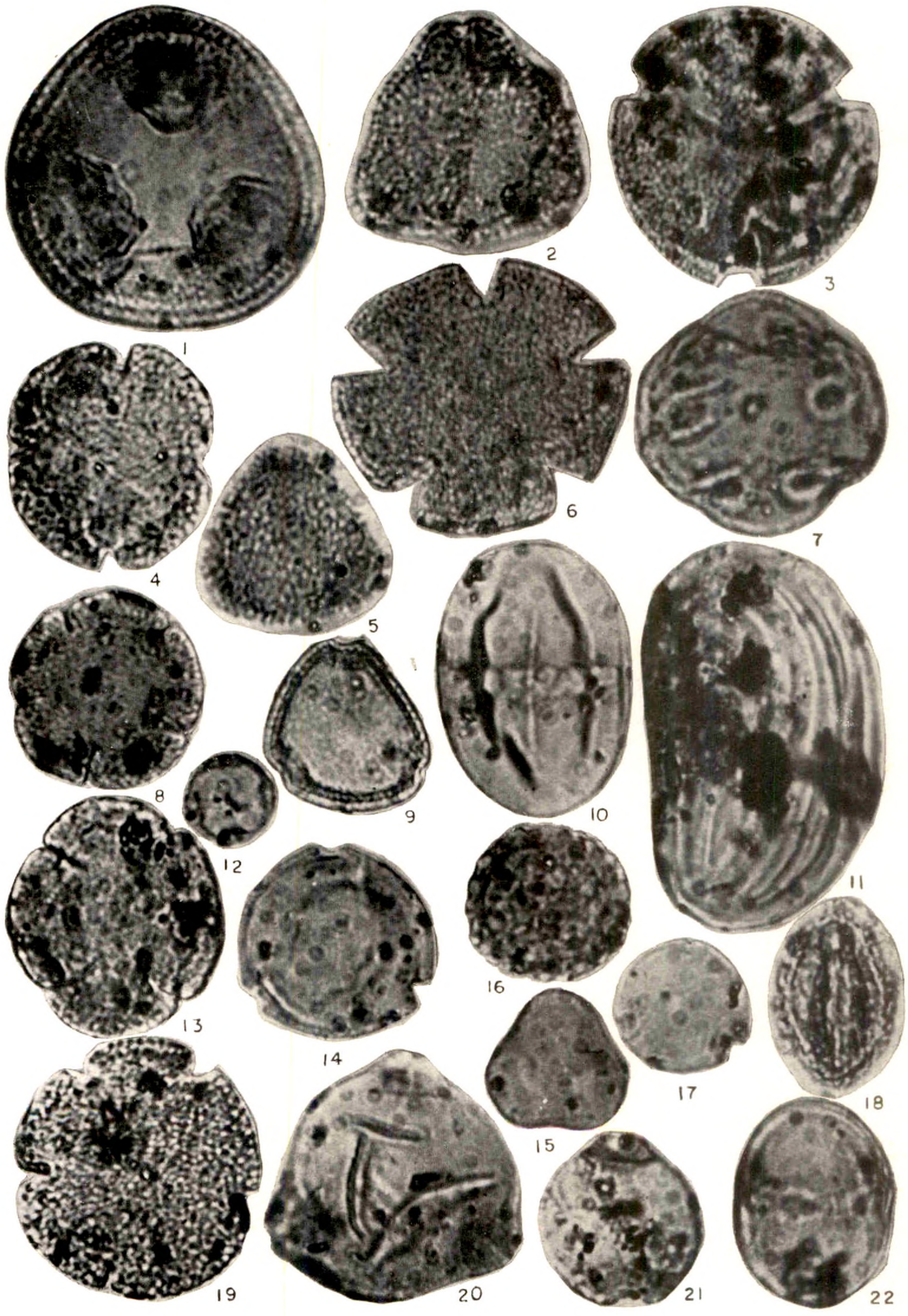
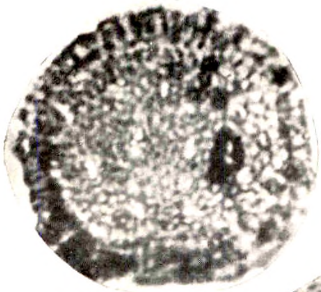
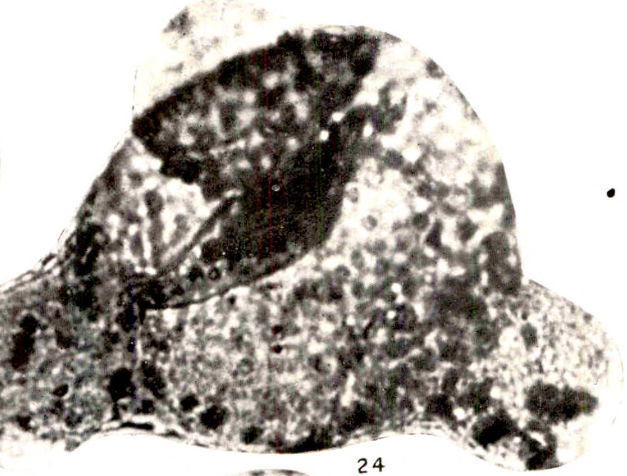
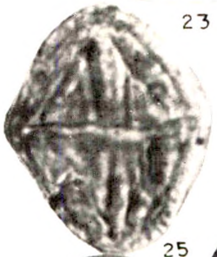
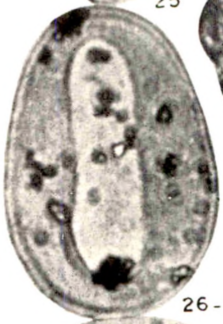


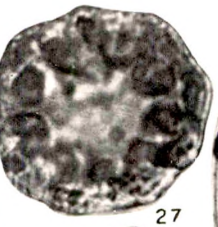
PLATE V

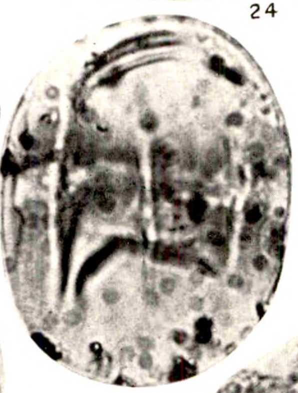

23

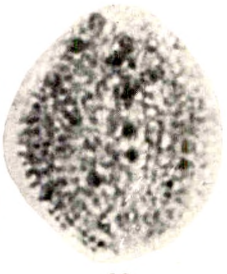

24

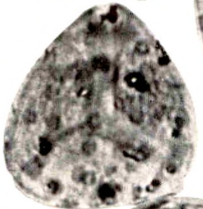

25

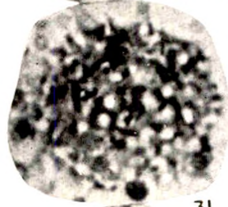

26-

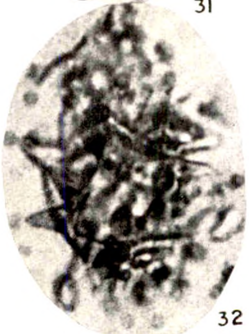

27

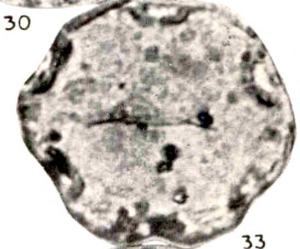

28

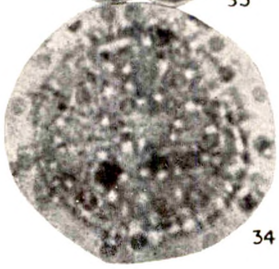

29


30


31


32


33


34

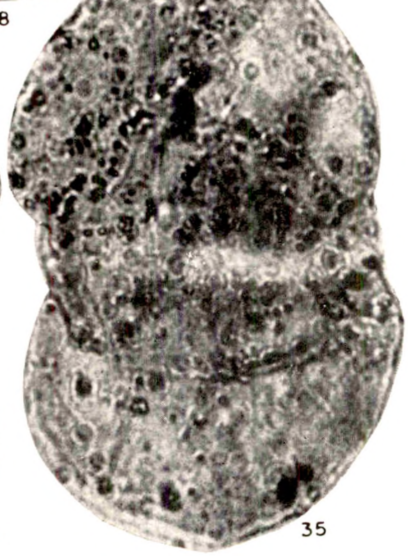
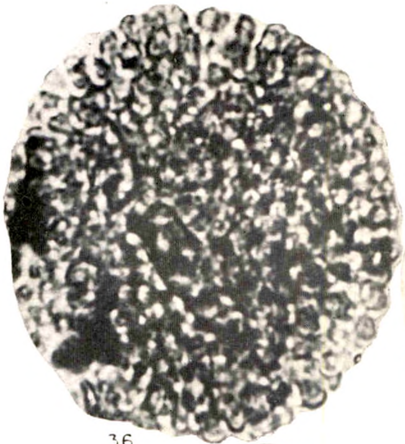
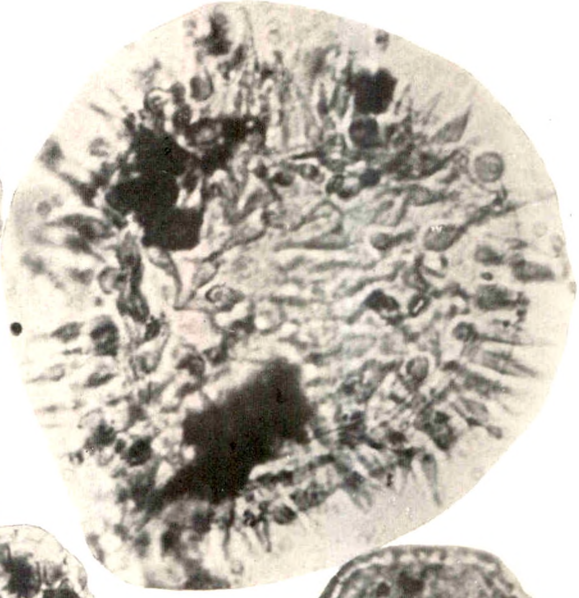
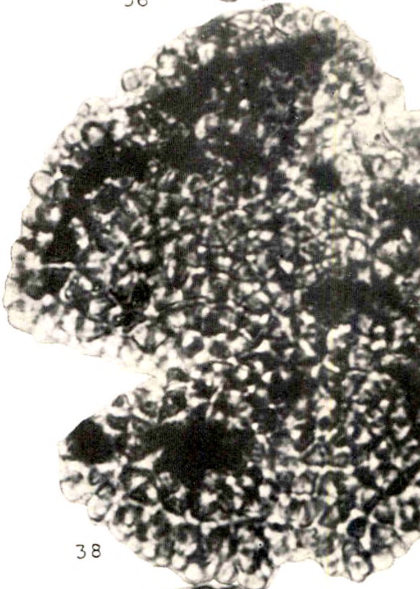
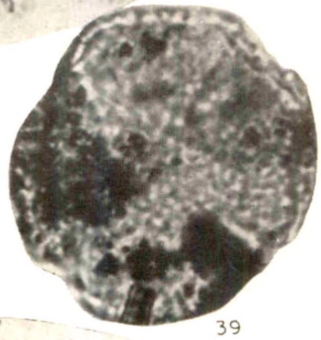

35

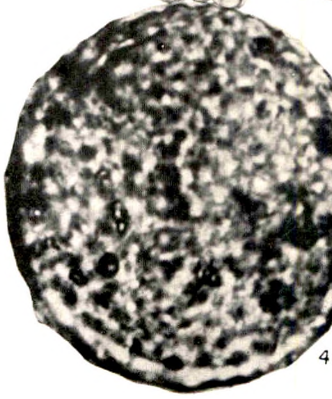
PLATE VI


36


37


38


39


40

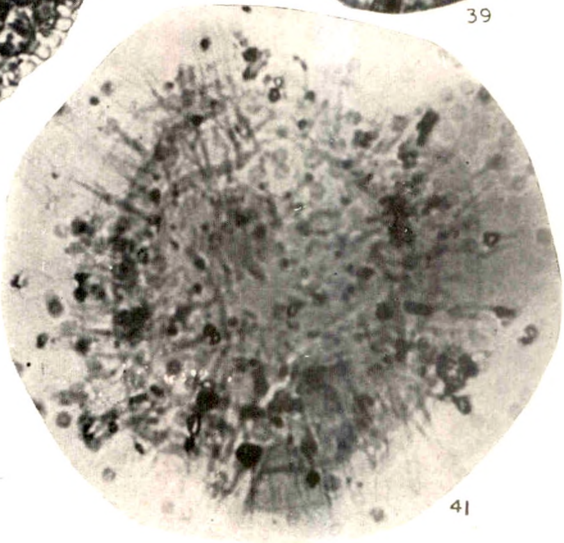
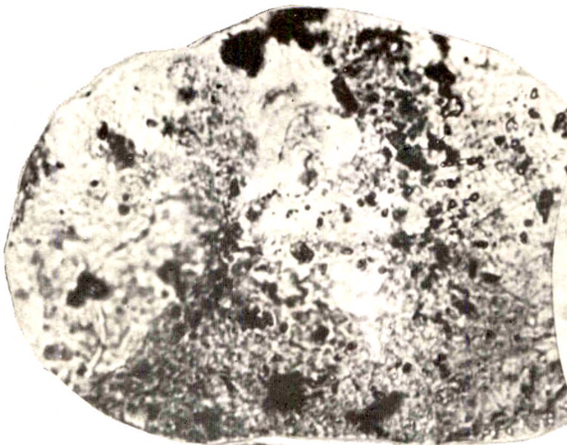
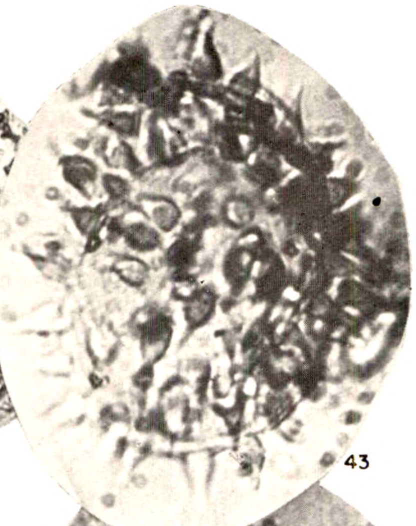
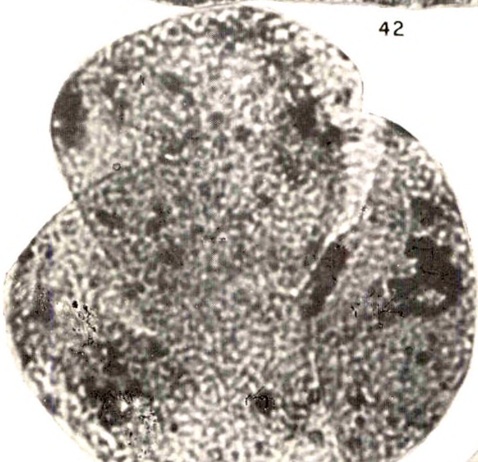
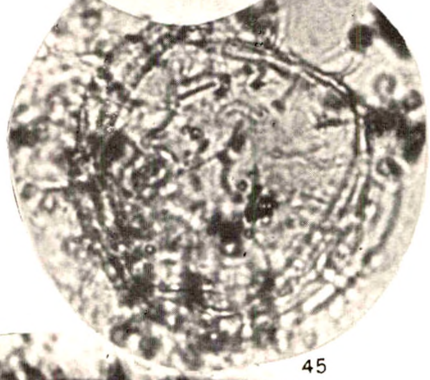

41

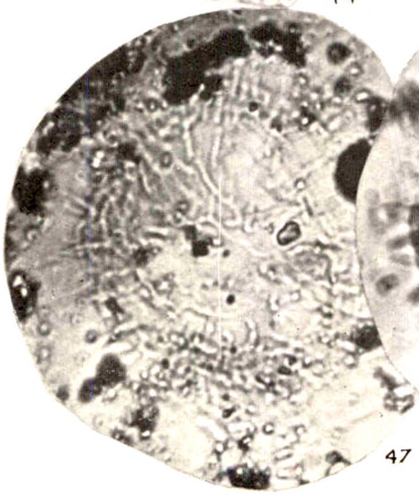
PLATE VII


42


43


44


45


47

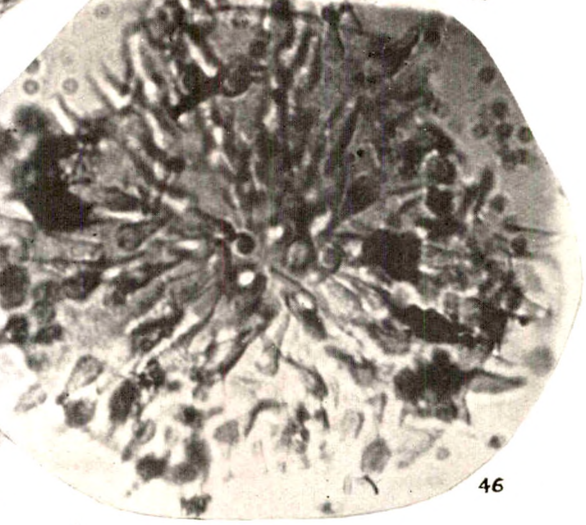
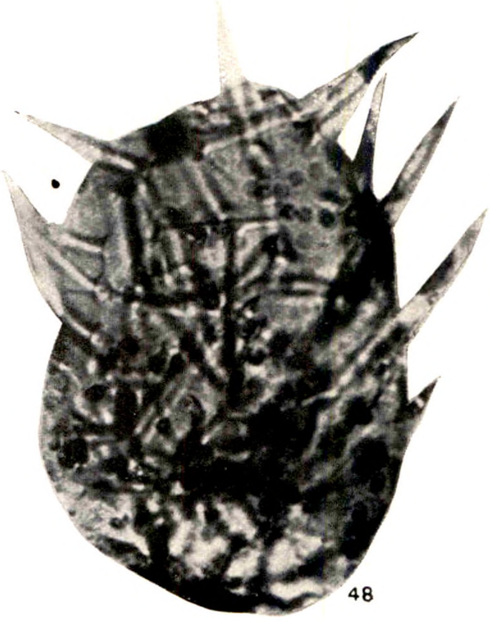
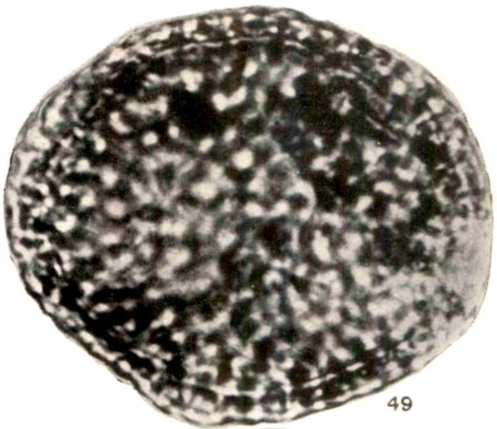

46

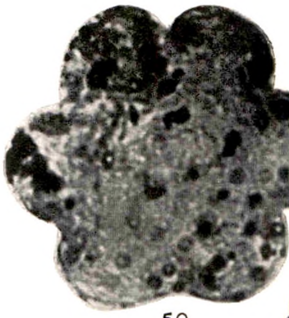
PLATE VIII



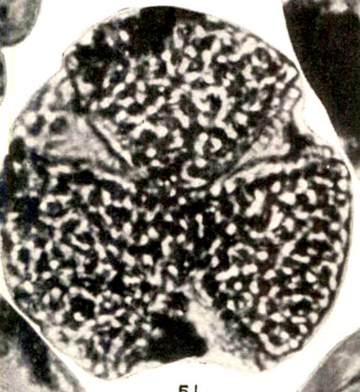
48



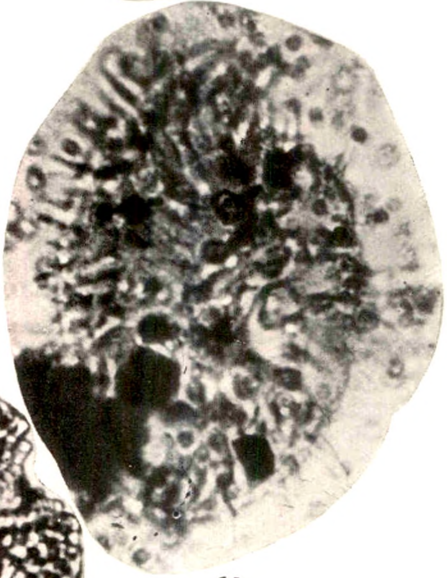
49



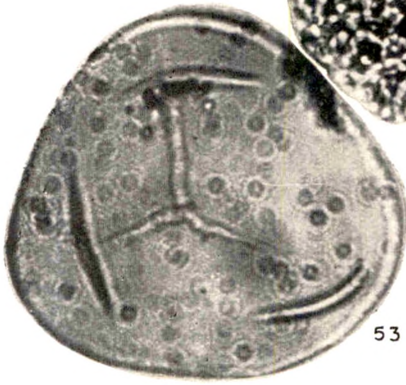
50



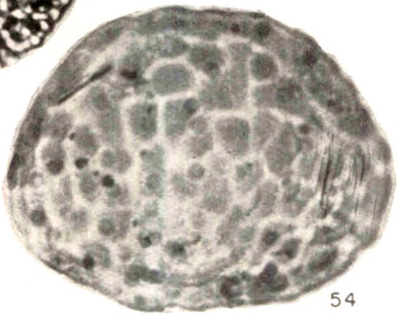
51



52



53



54

PLATE IX

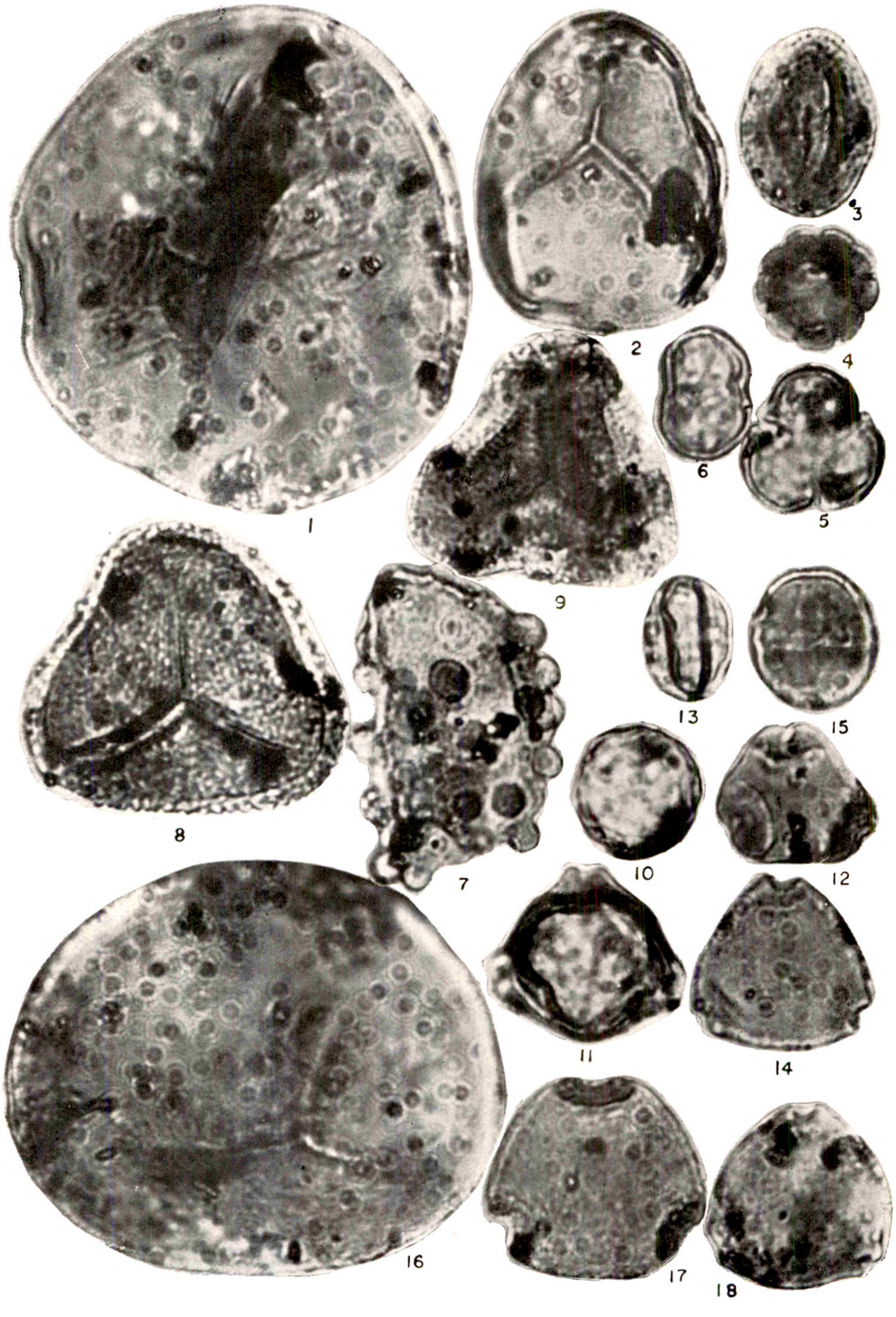
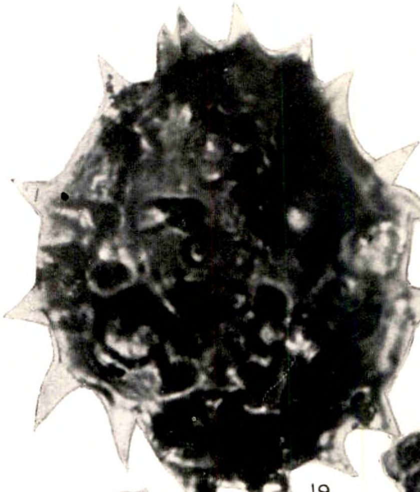
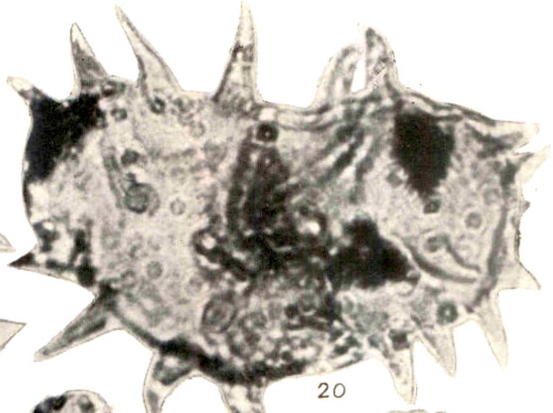
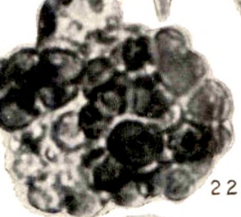
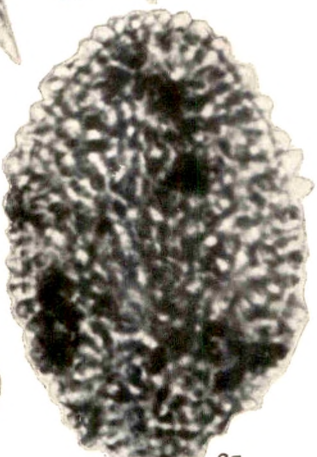


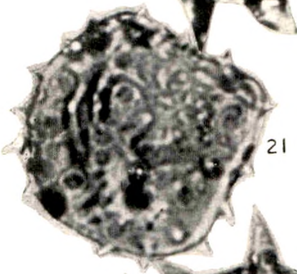
PLATE X

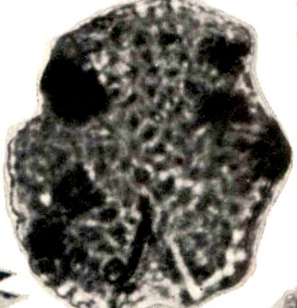

19

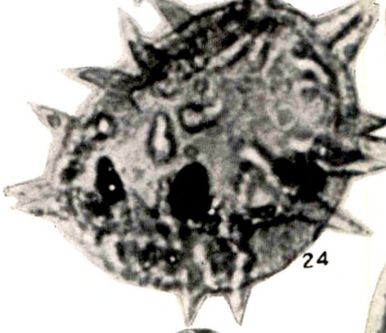

20

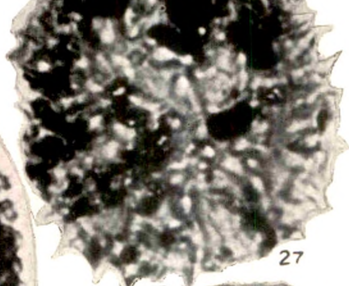

22

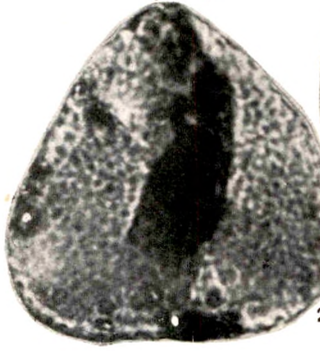

23

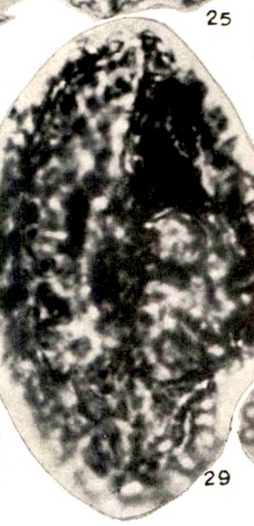

21


25


24


27


26


29

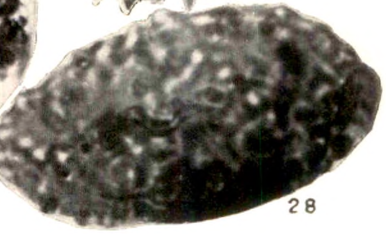
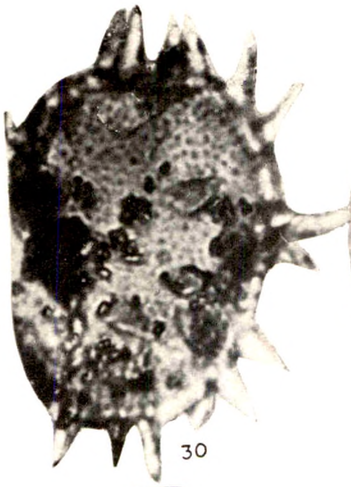
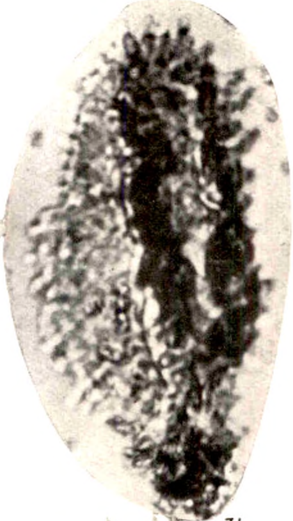
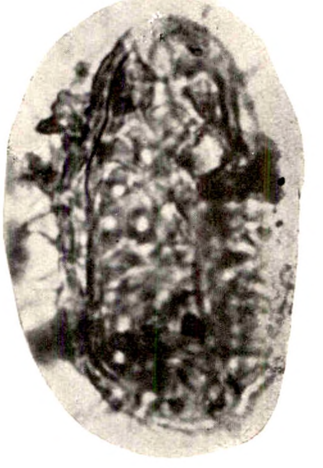
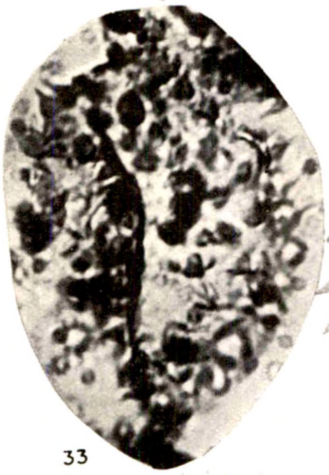

28

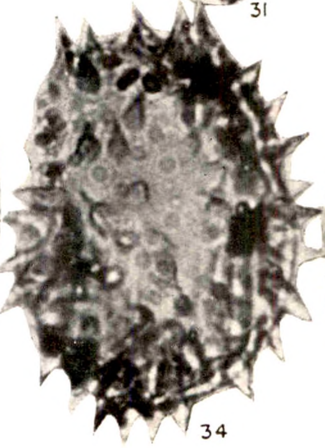
PLATE XI

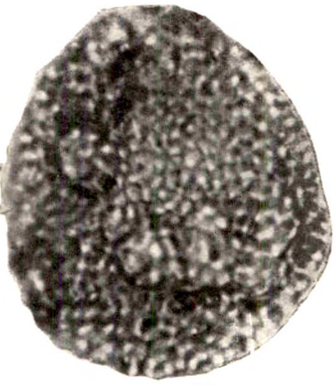

30

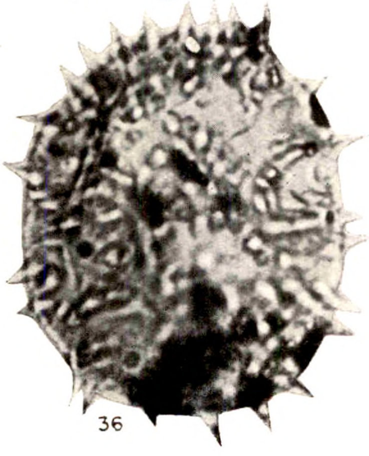

31

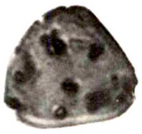

32

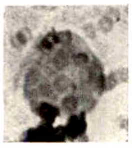

33


34


35


36


37


39

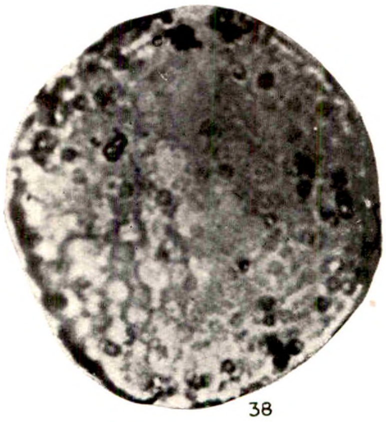
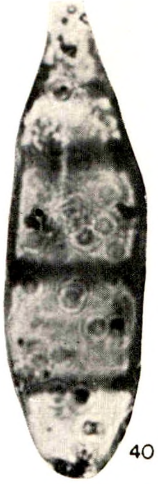
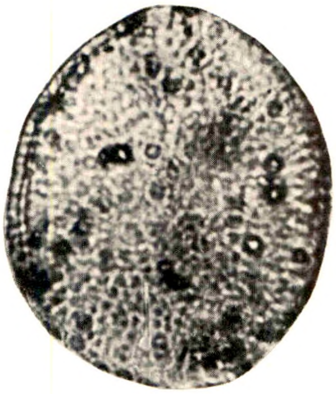

38

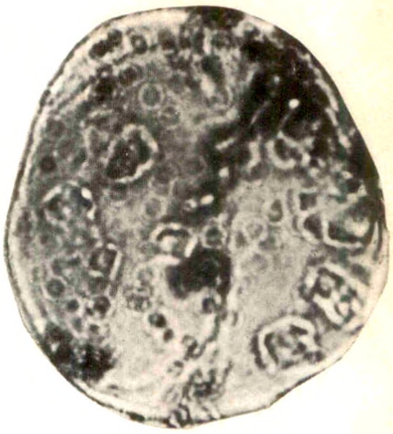
PLATE XII



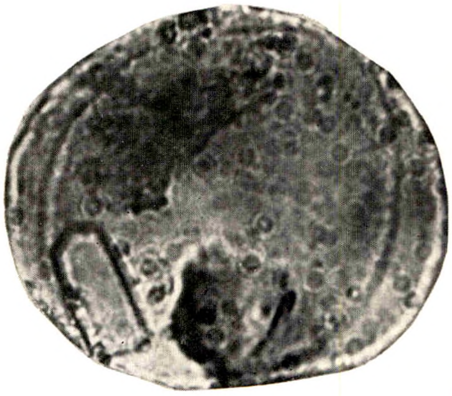
40



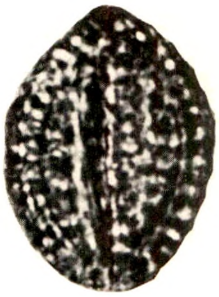
41



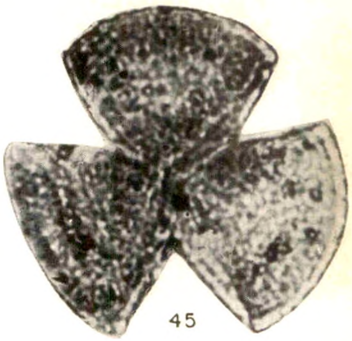
42



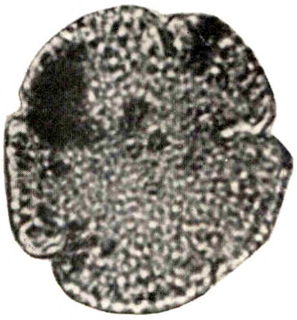
43



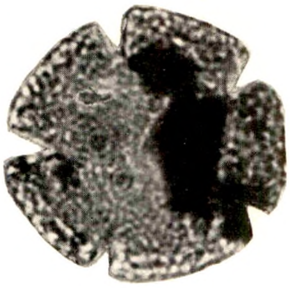
44



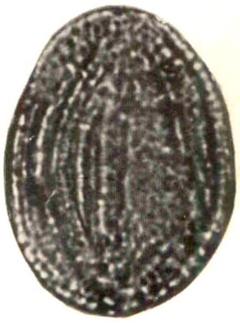
45



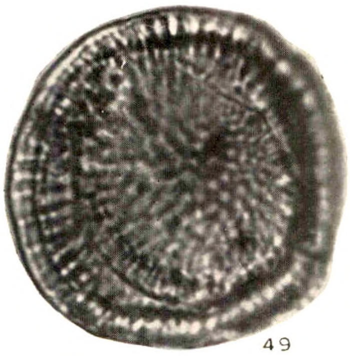
46



47



48



49

PLATE XIII

BULLETIN
OF THE
Geological, Mining & Metallurgical
Society of India

NO. 26 JUNE, 1962

PALYNOLOGICAL INVESTIGATION OF SIMSANG RIVER TERTIARIES, SOUTH SHILLONG FRONT, ASSAM.*

(Plates 1-5)

By

Subhendu Kumar Baksi

ABSTRACT

Spores, pollen and associated other organic microfossils like hystrichospherids/dinoflagellates and microforaminiferas are recovered and studied from a Tertiary sequence of sediments as exposed in the Simsang River sections, South Shillong Front, Assam. Palynological breakdown of this sequence of Simsang sediments resulted in the recognition of four broad and distinct Simsang Palynological Zones within the age interval, Middle Eocene—Miocene. These are from base upwards—Simsang Palynological Zone I or Simsang Sylhet Microflora (Mid. Eocene—Up. Eocene), Simsang Palynological Zone II or Simsang Kopili Microflora (Up. Eocene), Simsang Palynological Zone III (Oligocene) and Simsang Palynological Zone IV (Miocene). Each zone is elaborately described and discussed; comparison and correlation of the palynological assemblages of the respective zones and also, comparison of some of the individual elements of the said assemblages, are made with the counterparts found from the adjoining areas and also, in some cases, with those known from elsewhere. A few points regarding the vegetational habitats and environments, based on the evidences of these microfossils, are discussed.

Photomicrographic illustrations of the representative palynological elements of the individual palynological assemblages are accompanied. These representative constituent elements are described along with the explanation of plates. A schematic distribution-chart of the important Simsang palynological elements and a Location and Geological Map of the discussed area of Assam are enclosed herewith.

I. INTRODUCTION

This work reports the results of a preliminary palynological investigation of about 100 samples from a Tertiary geological sequence of outcrop sediments, as exposed in the Simsang or Someswari River sections (90° 39′—90° 42′E; 25° 12′—25° 21′ 10″N), South Shillong Front, Assam. Company geologists sampled these sections and also the other ones referred later. Precise dating of these rock sequences has been checked against foraminiferal evidences. Spores, pollen and associated microfossils like hystrichospherids/dinoflagellates and microforaminiferas have been recovered, studied and analysed from each of these dated lithologic sequences.

---

*Read before the Society on 23-2-62

Palynologically, from the base upwards, the whole Tertiary sequence, as exposed here, can be grouped under four, broad, distinct palynological zones. By the palynological zone is meant here a two dimensicnal (vertical and horizontal) sedimentary continuum which essentially produces a distinguishable palynological assemblage. The following are the palynological zones from base upwards against respective age and rock units :

TABLE I

Rock Unit		*Simsang Palynological Zone* (with approximate thickness)	*Age*
Surma or Surma-equivalent Series		Simsang Palyn. Zone IV (1600′)	Miocene
Barail or Barail-equivalent Series		Simsang Palyn. Zone III (3600′)	Oligocene
Jaintia Series	Kopili Formation	Simsang Palyn. Zone II (1050′)	Up. Eocene
	Sylhet Formation	Simsang Palyn. Zone I (900′)	Up. Eocene-Mid. Eocene

Excepting Sylhet and Kopili Formations of the Jaintia Series, the precise correlation of the lithology-types of the other two rock units with the type Barails and Surmas is not understood and that's why Barail or Barail-equivalent and Surma or Surma-equivalent groups of rocks have been mentioned here. Earlier works (Evans 1932, Ghosh and Banerjee 1952, etc.) show the direct onlap of Surma group of rocks over the Jaintia Series in this area, without the intervention of Barails. Whatever be the rock-stratigraphic status of these two groups of rocks, the resolution of which is beyond the scope of the present work, the presence of Oligocene and Miocene palynological assemblage in this area and also, the adjoining other areas (geographical coordinates referred later) of South Shillong Front is emphasized and these occurrences have really a significant bearing on the Tertiary geology of this part of Assam.

Comparison and correlation of the palynological assemblages of respective palynological zones of this area and also, comparison of some of the individual elements of the said assemblages have been made with the counterparts occurring in the adjoining areas and also, with those known from elsewhere.

Figure 1 represents a schematic distribution-chart of important types of spores, pollen and associated microfossils obtained in this area. Only the relative frequency of occurrence of them in the individual samples has been taken into account and so, the thickness-variation of the frequency markings is only schematic.

Location and Geological Map of a portion of Assam Area (1" = 16 miles) accompanies the report (Fig. 2).

- Photographic illustrations of each zonal assemblage, consisting of most of the important constituents are accompanied in the Plates 1-5. There are many more grains which could not be illustrated but are mentioned in the description and comparison of palynological zones.

Most of the grains obtained here are new excepting a few which are reported by Biswas in a previous paper that is in course of publication.

II. LITHOLOGY & MACERATION

Lithology regulates the type of maceration an individual sample is to undergo for the concentration of spores, pollen and associated microfossils. Accordingly, maceration procedure and duration of chemical treatments involved in those procedures are determined judging the individual lithology of the samples.

Lithology types that have been chosen for the study are mostly shales of varied kinds. These are in general, black carbonaceous shales (palynologically most productive), limy shales, fragmentary coals & argillaceous limestones and a few compact sandstones have also been tried and the results are found to be useful.

Basic usual maceration procedures have been followed for the above lithology types with variation in the duration of chemical treatment. Excepting coal, all other samples are treated first with Conc. HF acid to remove the arenaceous components of the samples ; next, if needed, the sample undergoes oxidation with the help of an oxidising agent *viz.* Schultze's solution ($KClO_3 + HNO_3$: 1:3) and after this stage, if needed, it is treated with an alkali, generally KOH (10%) to remove humic acids left after oxidation. Centrifuging and washing are the repeated operations after each stage of chemical treatment. Temporary slides are checked after 'HF stage', 'Schultze's stage' and 'Alkali stage' to determine if at all the next step is necessary to follow (because, for instance, it is sometimes found that the grains after HF stage are clean-liberated and the next oxidation-stage affects the anatomy of the grains) or if necessary, to determine, with experience, the probable required duration of the next treatment. This check is essential. Otherwise, it is noticed that either the sample is over-macerated or under-macerated with respect to the spore, pollen grains.

The following are, in brief, the generalised maceration procedures adopted against the individual lithology type of the Simsang River area :

TABLE II

black carb-shale : HF + Schultze's soln. + Alkali

limy shale : HCl + HF + if needed, Schultze's soln. + if needed, Alkali

ferruginous shale : same as above

sandy shale : HF + if needed, Schultze's soln. (rarely needed)

coal : Schultze's soln. + Alkali

sandstone : HF + if needed Schultze's Soln. (very rarely needed)

III. MORPHOLOGY & CLASSIFICATION

Morphological studies for classification of the angiospermic pollen grains include here those of, in order of importance, apertural structures (of both the ectexine and endexine), all exine structures and size and shape (with due considerations to compressional effects). For those grains which have been found to be morphologically similar to or identical with their living counterparts botanical sub-family, family or group name has been prefixed for nomenclature. Otherwise, artificial morphological classification on the lines adopted by Wodehouse (1935) and Iversen and Troels-Smith (1950) has been adopted.

Gymnospermous pollen consists here mainly of winged Conifer types and a few monocolpates, probably of Ginkgo affinity. *Coniferipites* and *Ginkgopites* are named accordingly.

Germinal aperture has been much stressed for the classification of the spores obtained here. The spores are either alete, monolete or trilete. Recognized morphological spore generic names like *Leiotriletes* (Naumova 1937) Pot. & Kr. 1954, *Laevigatosporites* (Ibrahim 1933) emend. Schoff, Wilson and Bentall 1944 have also been used.

The taxonomic position of hystrichospherids is still not well known. Some of the morphologically very distinct types amongst them have been binomially named. Those, which seem to run the possibility of being identified with the dinoflagellates have been left unclassified. Morphologically it is rather difficult to distinguish some hystrichospherids from the dinoflagellates

It has not been possible to classify the megalospheric tests of microforaminiferas ; probable existence of relationship of a few of them with the known counterparts is guessed.

Taxonomic nomenclatures of the forms earlier described by Biswas are mentioned.

It should be borne in mind in this connection that the foregoing account is not a detailed taxonomy, on the other hand, this is thought to be the minimum necessary, as demanded by the present scope of the work.

IV. PALYNOLOGICAL ZONES

Innumerable spores and pollen together with associated other microfossils are obtained from the different samples from base upwards the Simsang geologic sections. Of them, the study of distribution of certain distinct or key elements, more or less constant association of a few elements and/or the relative abundance of a few of them at places in the vertical geologic sequence results in the palynological breakdown of the sequence into four, broad, distinct palynological zones. The horizontal extension of these erected zones is tested by way of comparison and correlations with the different palynological assemblages obtained in other adjacent vertical geologic successions.

Table 1 represents the four different palynological zones obtained at Simsang River sections against respective geologic age and rock-units. These palynological zones represent only the distinct broad groupings. The richness and variety of spores and pollen in the three particular Simsang Palynological zones *viz.* Simsang Palynological Zone I, Simsang Palynological Zone III and Simsang Palynological Zone IV may help in finer palynological subdivisions within the respective zones on further detailed examination. There is also a possibility of finding a distinct palynological zone (? Paleocene-Lr. Eocene in age) at the very base of the section. The reason behind this postulation is that two vertically very adjacent samples in the basal part of the Simsang geologic section produce a limited number of spores and pollen (fig. 6 of Plate 1 and fig. 20 of Plate 2 are two distinct types amongst them, illustrated here within the Simsang Palynological Zone I). But on the basis of only two such samples, a separate palynological zone in the basal part of the section is not erected. Better sampling and future work with this bias may reveal something worth for a separate palynological zonation.

Elaboration of each palynological zone *viz.* (A) Simsang Palynological Zone I, (B) Simsang Palynological Zone II, (C) Simsang Palynological Zone III and (D) Simsang Palynological Zone IV follows :

(A) Simsang Palynological Zone I

This is the basal palynological zone in the Simsang geological section. The zone produces an extremely rich microflora, together with a large number of hystrichospherids and microforaminiferas. This microflora may also be called Simsang Sylhet Microflora because of its derivation from Sylhet Formation. Almost all the samples in general are richly fossiliferous. Shales, carbonaceous shales and fragmentary coals constitute the lithology of these spore-pollen rich samples. Hystrichospherids and microforaminiferas are seen to occur in excessive abundance in the argillaceous bands which sometimes rarely occur in limestones, although they are also present in the shales.

The types and nature of occurrence of spores, pollen and associated other microfossils that characterize the palynological assemblage of the Simsang Palynological Zone I are the following (figs. 1-26 of Plates 1-2 represent the illustrated palynologic assemblage of the Simsang Sylhet Microflora):

(1) *restricted occurrence* of a few ornamented *tricolpate/tricolporate pollen* related to *Caesalpineaceae* and *allied group* (figs. 11, 12, 13, and 14 of Plate 1 representing a few of them),

(2) *restricted occurrence* of a number of *ornamented polycolpate/polycolporate* pollen species, such as those of *Pentacolpopites*, *Hexacolpopites* and *Octacolpopites* (figs. 5,6,7,8,9 & 17 of Plate 1 representing a few of them),

(3) *restricted occurrence* of a *tubercle-bearing pollen*, *Nonaperturipites evansi* Biswas (represented by fig. 3, Plate 1),

(4) *constant presence* of a few *Palmae* pollen (a characteristic species, *Palmaepites slimsliti*, represented by fig. 4, Plate 1),

(5) *frequent occurrence* of a few *spinose* pollen—some of them being *acolporate*, a few *monocolpate/monosulcate* and some others, *tricolpate;* (figs. 18, 21 and 22 of Plate 2 representing a few such grains),

(6) rare occurrence of *morphologically distinct monocolpate* species (fig. 19 of Plate 2 representing the species),

(7) presence of *granulose tricolporate* with *robust colpae* and *large pores* at the equator, probably related to *Araliaceae* (fig. 15 of Plate 1 representing the type),

(8) frequent association of an *inaperturate*, morphologically distinct grain, *Foldexina inaperturata* (represented by fig. 16, Plate 1) and

(9) occurrence of a few species of *Hystrichosphaeridium* (represented by figs. 25 & 26 of Plate 2).

Besides these, there occur a large number of other tricolpate and tricolporate pollen, some small triporipites (fig. 10 of Plate 1 representing a distinct type), granular tetracolpate and decacolpate pollen, rare Conifer pollen, a number of hystrichospherids (there are definitely three types amongst them and a few stand the possibility of being relegated to dinoflagellates) and a large number of microforaminiferas (figs. 23-24 of Plate 2 representing only two types).

Significantly, pteridophytic spores are few in number compared with that of angiospermic pollen. Figs. 1-2 of Plate 1 represent two types of pteridophytic spores that are frequently present in the Sylhet microflora. Of course, uniserial double-chambered to multi-chambered fungal spores are very frequent. Oil alga related to *Botryococcus* are also found to occur in the assemblage.

Correlation and Comparison :

Similar to identical species of spores, pollen and hystrichospherids as obtained in the Simsang Sylhet Microflora have been found from the equivalent horizons from the adjoining river sections like Dareng River (90° 30′E : 25° 10′N), Umiam River (91° 38′E : 25° 11′N), and Rongra River (90° 47′E : 25° 13′N) sections. Particular mention may be made of the occurrences of similar to identical polycolpates, tricolporates related to *Caesalpineaceae* and *Araliaceae*, spinose pollen and a few hystrichospherids in these sections.

Work on the stratigraphy of Mahadeo, Langpar, Cherra and Tura Formations by Biswas (in course of publication) reveals the fact that most of the spore-pollen types that are obtained in the Simsang Sylhet Microflora are represented in the equivalent horizon there.

Lignites from Palana (Eocene), Bikaner, Rajasthan (Rao & Vimal 1952) are found to record an Eocene palynological assemblage of which a few pollen elements appear to be common with some of the grains from Sylhet microflora from the Simsang River Section, although the two areas are located far apart from each other. Comparable Palana grains may be mentioned as the polycolpates (like tetracolpate, pentacolpate and hexacolpate as represented by photos 23, 24 and 25 respectively of Plate XVIII), the heavily reticulate-ornamented tricolpate (like photos 13, 15, 16 & 21 of Plate XVIII), the smooth tricolpates (like photos 10, 14 & 20 of the same plate), and the fungal spores (like photos 2 & 3 of the same plate).

Vimal (1952) records a contemporaneous assemblage of spores and pollen from Dandot, W. Pakistan. Some of the *Polycolpopites*, *Tricolpopites* and *Triporipites* noted in the assemblage are comparable with some respective counterparts from the Simsang Sections. But, otherwisely, with the evidences of the assemblage of the abundant fern spores (mainly of *Ophioglossum*, *Lycopodium and Selaginella*), Dandot palynological assemblage differs from the Simsang Sylhet one.

Comparison of some of the elements of Simsang Palynological Zone I with the spores, pollen and other organic microfossils from as far as the Eocene of Maracaibo Basin of Northwest Venezuela (Norem 1955) is highly interesting. The tricolpates (as represented by figs. 13, 21 & 23 of Plate 1 and fig. 29 of Plate 2), the tetracolpates and pentacolpates (as represented by figs. 26, 27 & 28 of Plate 2), a monocolpate grain (probably of ? *Palmae* affinity) represented by fig. 30 of Plate 2 and the irregular tubercles-bearing inaperturate grain represented by fig. 9 of Plate 1 of the Venezuelean material are worth mentioning for such comparison. Like that of the Simsang Sylhet Microflora, a process-bearing hystrichospherid (slighly different from the Simsang grain) is also recorded from the Eocene palynological assemblage of the Maracaibo area of Venezuela

(B) Simsang Palynological Zone II

Simsang Palynological Zone I or the Simsang Sylhet Microflora is succeeded by the overlying Simsang Palynological Zone II or the Simsang Kopili Microflora.

Compared with richness of the Simsang Palynological Zone I, this zone can be said to be poorly fossiliferous. Unlike the continued richness of the samples of the Simsang Palynological Zone I, the samples of this zone are sporadically fossiliferous. Preservation of the grains in the sediments of this zone is also far from satisfactory.

Both positive and negative evidences have been considered for defining this palynological zone. Palynological assemblage of the Simsang Palynological Zone II is enumerated below (figs. 27-35 of Plate 3 represent the illustrated palynological assemblage of the zone) :

(1) *frequent and probably restricted occurrence* of a large, margin-folded pteridophytic spore, *Laevigatosporites kopilia* (represented by fig. 35, Plate 3),

(2) *frequent occurrence* of an *acolporate*, spinose pollen, *Acolporipites spinulosa* (represented by fig. 28, Plate 3),

(3) *? restricted occurrence* of *Ginkgopites dubia* (represented by fig 29, Plate 3),

(4) *appearance of a tri-spinose (?) hystrichospherid, Simsangia trispinosa* (represented by fig. 34, Plate 3),

(5) *quite frequent occurrences* of *process-bearing hystrichospherids* (fig. 32, Plate 3 represents only one such type) and

(6) occurrence of a few *small monocolpate* (represented by fig. 31. Plate 3), *tricolporate* (represented by fig. 30, Plate 3) and *triporate* pollen (represented by fig. 33, Plate 3).

Two principal negative evidences may be mentioned as

(7) *rare presence to complete absence of the characteristic Simsang Sylhet Microfloral elements* such as the *ornamented tricolpate/tricolporate* pollen of *Caesalpineaceae and allied group*, the *ornamented polycolpates*, the *tubercle-bearing* pollen, the *robust tricolporate* (related to *Araliaceae*), etc. and

(8) *remarkable difference* in the *relative frequency of occurrence* of a few pollen like the '*gemmate-syncolpate*' grains (figs. 37-39, Pl. 3), the *spinose pollen* (figs. 47-48, Pl. 4), *rare presence to complete absence* of the spores like *Schizaeaceaesporites* (*Aneimia*)/*Parkeriaceaesporites* (*Ceratopteris*), fig. 41, Pl. 3, etc. of the succeeding overlying zone which is discussed later.

In addition to the elements of the Simsang Kopili microflora as cited above, occurrences of the '*gemmate-syncolpate*' grain, pteridophytic spores, mainly *Leiotriletes* (fig. 27, Plate 3) and *Polypodiaceae* spores, *Palmaepites*, one or two *Conifer* pollen, moderate-size *spinose* pollen and a few *small* monocolpate and tricolpate pollen are also recorded. *Microreticulatipites* (cf. fig 20, Plate 2) and a striated monocolpate cf. *M. striaei* (fig. 19, Plate 2), although very rare, are still found to persist from the underlying Simsang Sylhet microfloral zone. These may also be inferred as the reworked grains due to their poor mode of preservation and impersistent occurrence.

The Simsang Kopili microflora and hystrichospherids, from the study of its assemblage, show a good contrast with the underlying Simsang Sylhet microflora but appear to be transitional with the succeeding, overlying, palynological zone. A few palynological elements which have gained dominance in distribution in the overlying zone begin appearing from this zone.

Correlation and Comparison :

The Kopili microscopic floral remains and hystrichospherids from Lubha River Section (92° 25′E : 25° 08′N) correlates well with the palynological assemblage of the Simsang Palynological Zone II. *Acolporipites spinulosa*, *Ginkgopites dubia*, *Laevigatosporites kopilia* and a few similar hystrichospherids are present in the equivalent horizons of both the sections. Only this Lubha section in particular, offers the closest parallelism of the palynological elements with those from the Simsang Kopilis.

The other stream sections like Prang River (92°16′ E : 25°08′N), Rongra River (90°47′ E : 25°15′ N) and the Um Shoryngkew River (91°33′ E : 25°10′N) are found to produce a few stray palynological elements from the equivalent horizons which show close affinities with some of the Simsang Kopili elements. But, since the study of the microfloras of the suspected Kopilis from the above river sections is merely based on almost one or two samples from each of these sections and again, these samples are not so richly fossiliferous to offer representative microfloral assemblage of the respective horizons, nothing more than a possibility of the existence of Kopili microflora and hystrichospherids in the respective sections is suggested herewith.

(C) Simsang Palynological Zone III

Next in overlying succession to the Simsang Palynological Zone II is Simsang Palynological Zone III of Oligocene age.

The samples within this zone may be said to be rich in spores and pollen together with occasional hystrichospherids. The preservation of the grains is satisfactory. As noted earlier, a few grains are common to both this zone and the zone succeeding below and as such, the delineation between these two zones is not as sharp as that between the Simsang Sylhet microflora and Simsang Kopili microflora. This is regarding the lower boundary of the Simsang Palynological Zone III. Regarding the upper boundary of this zone, it may also be said to be transitional with the succeeding palynological zone above.

The bulk palynological assemblage that distinguishes Simsang Palynological Zone III is enumerated below :

(1) *very abundant occurrence* of the '*gemmate-syncolpate*' pollen of Meyer 1958 (figs. 37-39, Plate 3),

(2) *first appearance* (from below top) of a *finely striated tricolpate* pollen, *Bauhinia burdwanensis* Biswas (fig. 46, Plate 4),

(3) *frequent association* of a *tubercle-bearing monolete Polypodiaceae spore*, *Polypodiaceaesporites tuberculensis* (fig. 40, Plate 3),

(4) *very frequent occurrence* of *smooth Leiotriletes*, particularly of an *exine-folded, short-trilete type*, *L. garoensis* (fig. 36, Plate 3),

(5) *frequent occurrence* of *Schizaeaceae/Parkeriaceae* spores, a type of which viz. *Schizaeaceaesporites knoxi* (fig. 41, Plate 3) may be relegated to the genus *Aneimia*,

(6) association of a *granular pollen-tetrad*, viz. *Tetradopites granularis* (fig. 42, Plate 4), not frequent, and

(7) *frequent occurrence* of a *group of spinose pollen*—some of them are *acolporate* (a type represented by *Spinosopites acolporata*, fig. 47, Plate 4), some of them *monocolpate* and some *tricolpate* (a type represented by *Tricolpopites spinosa*, fig. 48, Plate 4).

Besides these, a number of small tricolpate pollen (two types represented by *T. prolati* & *T. shorti*, figs. 44 and 45 respectively of Plate 4), tricolporate pollen (a type represented by *Tricolporipites minima*, fig. 43, Plate 4), triporate ones, some of the Simsang Kopili microfloral elements from below like *Monocolpopites broadcolpusi* (fig. 31, Plate 3), *Tricolporipites dicoti* (fig. 30, Plate 3) and *Simsangia trispinosa* (fig. 34, Plate 3), a few Conifer pollen and a number of fungal spores are found to be associated with the palynological assemblage of this zone. Process-bearing hystrichospherids (like Fig. 32, Plate 3 of Simsang Kopili microflora) are very rare to absent in this palynological zone.

Three vertically widely separated different levels within the zone are found to record a marked concentration of three different groups of spore-pollen elements. Of these, the lowest one shows a remarkably high concentration of the '*gemmate syncolpate*' grain, the next higher one is found to contain a relatively high frequency of occurrence of *Leiotriletes* and the highest level records comparatively a good number of ribbed spores of *Schizaeaceae/Parkeriaceae* group. These features are simply mentioned here without assigning any stratigraphic value to them. As noted earlier, such a thick zone with a rich palynological assemblage is liable to further finer sub-divisions on detailed work. These features, as mentioned above, may help in this respect.

Correlation & Comparison :

The '*gemmate-syncolpate*' grain-packed level of the Simsang Palynological Zone III, as mentioned earlier, stands out to be a very well-defined one when the equivalent horizons from other river sections of the South Shillong Front area are examined for palynological contents. It is noticed that this horizon, rich in '*gemmate-syncolpate*' grains of Meyer 1958, can be traced in the definite Laisongs of Sonai River (91°42'20" E : 25°10'30" N), Hari River (92°13' E : 25°09' N), Prang River (92°16'E : 25°08' N), and as far east as Lubha River (92°21' E : 25°05'N) sections. The remarkable abundance of this grain is generally met with in the base of the Laisong Formation of these river sections. Similar *Leiotriletes*, *Polypodiaceaesporites*, *Spinosopites*, spinose *Tricolpopites*, *Schizaeaceaesporites/Parkeriaceaesporites*, *Simsangia* and fungal spores are also found along with the '*gemmate-syncolpate*' grain, in the referred river sections. Comparable high abundance of *Leiotriletes* is noted from the Barails of Lubha River (92°21'E : 25°05'N) only.

The Laisong Formation as exposed along the Haflong-Silchar Road section is also found to record similar *Spinosopites* and spinose *Tricolpopites*, *Leiotriletes* and *Polypodiaceaesporites* along with the *Simsangia trispinosa*. The similar relative abundance of *Schizaeaceaesporites/Parkeriaceaesporites* is noticed in the Renjis from Haflong-Silchar Road Section.

Based on Meyer's work (1958), another interesting correlation can be made with the subcrop Barail Series (9,000-10,000 feet depth) of Nahorkatiya Oilfield from Upper Assam. He reports the occurrence of the '*gemmate-syncolpate*' grains (figs. 5-6, Plate 24), the *Ceratopteris* (*Parkeriaceae*) type spore (fig. 1, Plate 24), which slightly differs from the corresponding Simsang *Schizaeaceae/Parkeriaceae* spores, particularly *Schizaeaceaesporites knoxi* as illustrated here (fig. 41, Plate 3) and *Polypodiaceae*-spore along with the many monocolpate, monosculcate palm type pollen and and tricolpate ones from the said horizon. He observes that *Ceratopteris*-type spore occurs relatively with high frequency and the age of these samples is of Middle Oligocene or younger age. The relatively abundant occurrence of similar *Schizaeaceae/Parker iaceae* (*Ceratopteris*) types of spores towards the top of the Simsang Palynological Zone III (correlated with the Renji occurrences of abundant similar spores from Haflong-Silchar Road section) also agrees with Meyer's observations regarding the probable age. The detailed palynological studies of the whole vertical sequence of the subcrop Barails of that area will reveal many interesting results.

(D) Simsang Palynological Zone IV

Simsang Palynological Zone IV of Miocene age is found to be the topmost palynological zone in the Simsang River sections. This zone transitionally overlies the Simsang Palynological Zone III that immediately succeeds below.

The samples within the zone are generally rich in spores and pollen with little amount of hystrichospherids and microforaminiferas. Preservation of the grains on the whole is good.

The spore-pollen assemblage that characterises the Simsang Palynological Zone IV consists of the following :

(1) *abundant occurrence* of *two-winged Conifer* pollen; many of them appearing for the first time from below upwards in the sequence. Mention may be made of *Coniferipites garoensis* (represented by fig. 49, Plate 4), *Con. abiesimilis* (represented by fig. 52, Plate 4 and Fig. 59 of Plate 5), *Con. wilsoni* (represented by fig. 60, Plate 5), *Con. chattacharai* Biswas (represented by fig. 61, Plate 5) and an one winged pollen related to *Tsuga* (not illustrated),

(2) *frequent occurrence* of a *group of ribbed spores*, some of which are related to *Parkeriaceae* (particularly the genus *Ceratopteris*) and some of them may be relegated to *Schizaeaceae* (particularly the genus *Aneimia*) ; *Ceratopteris macrocostata* Biswas (represented by fig. 53, Plate 4) and *Schizaeaceaesporites/Parkeriaceaesporites sp.* (represented by fig. 54, Plate 5) are two such types,

(3) *first appearance*, from below top, and *continued occurrence* of a *Polygonaceae* pollen, *Polygonaceaepites zonoides* (represented by fig. 58, Plate 5),

(4) *frequent occurrence* of a *small*, *bordered spore*, *Densexinosporites minuta* (represented by fig. 57, Plate 5),

(5) presence of a few morphologically distinct fungal remains like *Fungus striata* (represented by fig. 50, Plate 4) and *thyrothecium remains of Microthyriaceae*, a type of which, in particular, resembling *Microthyriacites edwardi* Rao 1959 (1958) from Miocene of Warkali, Kerala,

(6) occurrence of a *large*, *striated pollen*, *Tricolpopites radiistriaei* (represented by fig. 55, Plate 5) and

(7) occurrence of a *granulose, tricolpate* pollen, *Tricolpopites granulosa*, (represented by fig. 51, Plate 4) and a triporate pollen *Triporipites crescentipora* (represented by fig. 56, Plate 5).

In association with the above, a host of other tricolpate pollen, triporate pollen and tricolporate pollen accompany the assemblage. A few spinose pollen like *Spinosopites acolporata* and *Tricolpopites spinosa*, plus other grains, such as *Bauhinia burdwanensis* Biswas, *Polypodiaceaesporites*, *Leiotriletes* and the '*gemmate-syncolpate*' grain of Meyer 1958, from below, are found to continue to this zone (some of them may be doubted to be reworked occurrences). Process-bearing hystrichospherids/dinoflagellates are noticed only in one particular sample.

Simsang Palynological Zone IV is seen to contain a few reworked pollen types from Simsang Palynological Zone I or Simsang Sylhet microflora.

Correlation and Comparison :

There is a close agreement in the palynological assemblage between that of the Simsang Palynological Zone IV and the one obtained from the Surma Series as exposed in the Haflong-Silchar Road Section. Similar types of Conifer pollen and *Parkeriaceae/Schizaeaceae* spores together with the spores related to *Densexinosporites minuta* occur in the equivalent horizons from both the areas.

Similar two-winged Conifer pollen (so far as the Camera-lucida sketches, figs. 26 & 29, Plate 15, are concerned) are also reported from the Surma series of Assam by Sahni et al 1948 (1947).

Equivalent horizons, mapped as Surmas, from Chiku-Nulla (93°12'E: 25°07'N) and Jiri Gang (93°05'E: 25°0'N) sections reveal frequent occurrences of similar conifer pollen together with rare to occasional presence of *Parkeriaceaesporites/Schizaeaceaesporites*.

Some of the samples from the anticlines which are composed of outcrop Upper Tertiaries on the northern folded-belt tract of Tripura are cursorily examined for palynological contents. The examination reveals that similar assemblages of Conifer pollen together with occasional *Parkeriaceaesporites/Schizaeaceaesporites* and also, although rarely, other tricolpate pollen (including one identified genus, *Polygonaceaepites*) are found to be present in the known Surma series of Chattachara Anticline (92°30'E: 24°27'N), Bhairabi Anticline (92°40'E: 24°37'N), Jampai Anticline (92°17'E: 24°27'N) and Rengte Anticline (92°46'E: 24°30'N). The samples from these structures, in general, are only sporadically fossiliferous and are not so rich but even then, spore-pollen assemblages comparable to that of Simsang Palynological Zone IV are recognizably represented in the total population of spores and pollen contents.

About thirty-six different types of spores and pollen of Miocene age are described from Warkali lignites, Travancore, by Vimal (1953). It is seen that excepting for a few small tricolpate and tricolporate pollen, there is very little agreement between the overall palynological assemblage of Warkali and Simsang Palyn. Zone IV. Peculiarly enough, Conifer pollen, generally one of the most dominant constituents of palynological assemblage of Mio-Pliocene time, is entirely missing from the Warkali assemblage. Also, *Aneimia/Ceratopteris* types of spores that are so frequently present in this Simsang Palyn. Zone are found to be absent in the same.

HABITATS

The differentiated microfloral sequence as obtained in the Tertiary of Simsang River Sections of Assam is, as elsewhere, an expression of a variety of habitats of the then different vegetational communities. To work out a complete habitational history of the vegetation during Eocene-Miocene time-span with the help of spores, pollen and associated microfossils requires the most important pre-requisite—the natural affiliation, as far as possible, of these palynological elements and of course, with accuracy. And then, it is required to proceed with the factors like climate, topography etc, that controlled the growth, multiplication and distribution of the identified plant communities in time and space. But in this case, the data at hand at this stage of the work, are too incomplete to permit building up a complete habitational history of the vegetation of the area. Accordingly, nothing more than a few relevant points regarding the habitats as observed in the Simsang microfloral sequence is discussed here.

The Eocene assemblage of spores and pollen of Simsang River, mainly tree-pollen that are relegated to different plant groups like *Leguminosae, Araliaceae, Compositae, Betulaceae* ? *Nelumbiaceae, Araceae, Palmae* etc. and which has a close parallelism with the tropical Eocene assemblage of Venezuela perhaps also indicates a rain-forest type habitat of a tropical area. The palynological assemblage of Simsang Palynological Zone I, in particular, is seen to record a dominant occurrence of angiospermic elements with rare pteridophytic spores. This differential distribution is either due to different kinds of preservation or is in response to some different ecologic factors controlling the growth and thriving of the dicots over the pteridophytes. Slightly local brackish influence on depositional conditions of the Sylhet microflora is attested by the presence of some hystrichospherids in a few samples and this influence appears to be more pronounced in the succeeding Kopili microflora where a continued association of hystrichospherid with the microfloral elements is seen to be present.

Meyer (1958) observes on the palynological association of the Barail subcrops from Brahmaputra valley of Upper Assam that this kind of association, particularly the high frequency of spores related to a fresh-water fern *Ceratopteris* and palm pollen, would point to a fresh-water swamp flora, which habitat still persists in South America. Here, in the palynological assemblage of Simsang Palynological Zone III, occurrence of both the spore-pollen types is noted but the higher frequency of the spores related to *Ceratopteris* (*Parkeriaceae*) or *Schizaeaceae* is noted in the younger part of this zone and so, that swampy habitat may apply only to this part of the zone. Until the natural affinity of the '*gemmate-syncolpate*' grain of Meyer 1958 is established, the ecologic factors behind the extremely abundant occurrence of these grains towards the base of this palynological zone can hardly be understood.

Conifer pollen occur dominantly in the Miocene Simsang Palynological Zone IV assemblage. The dominant occurrence of Conifer pollen in the Miocene sediments of this river section has a definite bearing on the then surrounding topography and climate of the area. From the present day high-altitude distribution of Conifer vegetation, raised topography and initiation of cold climate (which attained its peak through Pliocene in Pleistocene time) may be thought to be the guiding factors in ushering in a thriving Conifer forest nearby the site of deposition of these sediments. These factors, again, may be consequently related to the third or major upheaval of the Himalayas on the northern part of this basin of deposition. Upper Tertiary Conifer dominance is a recognised feature in other parts of the world, too. For instance, initiation of arcto-Tertiary flora during the beginning of Miocene time and later (Plio-Pleistocene time), and dominant Conifer forest vegetation are inferred by Norem (1956) with the help of spores and pollen as recorded in the Tertiary sequence of California. Striking dominance of Conifer pollen (mainly *Podocarpus* type) in the Oligo-Miocene sediments of Venezuela is noted by Kuyl et al (1955) and this dominance of Conifer pollen, living trees of whose counterparts being restricted in distribution about 2000 meters (approx.) high, is also thought to be connected with the origin of Venezuelan Andes.

Although *Microthyriaceae* has a wide ecologic range, Edwards (1922) suggests that these fungi are generally associated with Conifer forests. The association of Conifer pollen and the fungi definitely related to *Microthyriaceae* in Simsang Palynological Zone IV may be recalled in this context.

Unlike the facies-free elements as most of these spores and pollen are, the hystrichospherids/dinoflagellates and microforaminiferas are facies-restricted biotas and accordingly, behave sensitively to the changes of facies. At a few levels in the Simsang River sequence of sediments, particularly very prominently in the intra-limestone thin argillaceous bands of Simsang Palynological Zone I, this microforaminifera-hystrichospherid/dinoflagellate association is noticed. Experience with this association obtained in the preferred types of sediments leads the author to believe a marine influence of the sediments in which they are found, the degree of which is very hard to establish in the context of the present knowledge about them. Sometimes, only the hystrichospherids/dinoflagellates without the other associate *viz.* microforaminiferas and vice versa are found to occur, in which case, also, a brackish to marine influence in the depositional conditions of that part of the sediments may be guessed.

ACKNOWLEDGEMENT

This work has been done in the Geological Laboratory of Standard-Vacuum Oil Company, Producing Operations, Calcutta. The author expresses his deep indebtedness to this Company and especially to Mr. R. G. Prough, for permission to publish this work. His grateful thanks are due to Mr. B. Biswas for checking the taxonomic nomenclature of the forms included in this paper that were previously described by him,

EXPLANATION OF PLATES

PLATE 1.

Fig. 1 *Leiotriletes dehiscensi* sp. nov., proximal view; longest axis 39 microns; spore-coat very thin, smooth; trilete short and 'gaping'; sample no. VD. 45; photographic serial number 6018; x1125.

Fig. 2 *Leiotriletes virkkii* Biswas, proximal view; long. axis 41 micr.; sample no. VD 4I; phot. ser. no. 5988; x1125.

Fig. 3 *Nonaperturipites evansi* Biswas, oblique polar compression; long. diam. 36 micr.; sample no. VD. 29; phot. ser. no. 5947; x1125.

Fig. 4 *Palmaepites slimsliti* sp. nov., equatorial compression; long. diam. 39 micr., psilate; monocolpate, colpus—a pole to pole narrow uniform slit; sample No. VD 29; phot. ser. no. 5962; x1125.

Fig. 5 *Hexacolpopites sp.*, equat. compression; long. diam. 31 micr.; surface very finely granular; hexacolpate; may be an equatorial compression of *Erdtmania terminaliaformis* Biswas; sample No. VD 12; phot. ser no. 5887; x1125.

Fig. 6 *Tricolpopites sijuensis* sp. nov., equat. compression; long. diam. 33 micr.; surface ornamentation granular-punctate; tricolpate, colpae wide; sample no. VD 4; phot. ser. no. 6077; x1125.

Fig. 7 *Hexacolpopites sp.*, polar compression; long. diam. 29 micr.; sexine thick; surface granular-punctate, coarse to fine from equatorial periphery towards the polar central region; hexacolpate, colpae short; sample no. VD 29; phot. ser. no. 5943; x1125.

Fig. 8 *Pentacolpopites ? turaensis* Biswas, slightly oblique polar compression; long. diam. 28 micr.; surface finely granulose; pentacolpate, colpae short, imbricate in appearance due to ?compression; sample no. VD 14; phot. ser. no. 5913; x1125.

Fig. 9 *Pentacolpopites eocenica* Biswas, polar compression; long. diam. 31 micr.; sample no. VD 29; phot. ser. no. 5973; x1125.

Fig. 10 *Triporipites minuta* sp. nov., polar compression; long. diam. 17 micr; psilate; triporate, pores peripheral, medium-size; sample no. VD 29; phot. ser. no 5944; x1125.

Fig. 11 *Palaeocaesalpineaceaepites eocenica* Biswas, equatorial compression; long. diam. 37 micr.; sample no. VD 27; phot. ser. no. 5919; x1125.

Fig. 12 *Palaeocaesalpineaceaepites sp*, polar compression; long. diam. 33 micr.; surface reticulate, muri wider than lumina; tricolpate/tricolporate, colpae wide, extend to near the pole; sample no. VD 27; phot. ser. no. 5937; x1125.

Fig. 13 *Palaeocaesalpineaceaepites eocenica* Biswas, equat. compression; long. diam. 35 micr.; sample no. VD 29; phot. ser. no..5955; x1125.

Fig. 14 *Palaeocaesalpineaceaepites eocenica* Biswas, polar compression ; long diam. 36 micr. ; sample no. VD 29 ; phot. ser. no. 5954 ; x1125.

Fig. 15 *Tricolporipites aralia* sp. nov., equat. compression ; long. diam. 33 micr. ; surface very finely granulose ; tricolporate ; colpae wide and thick, extend from pole to pole with distinct slit-like pores on their equatorial region ; may be related to the pollen of *Araliaceae*; sample no. VD 27 ; phot. ser. no. 5927 ; x1125.

Fig. 16 *Foldexina inaperturata* gen. et. sp. nov., long. diam. 31 micr.; body always wrinkled with thin exinous cross-folds ; germinal aperture not visible ; sample no. VD 14 ; phot. ser. no. 5906 ; x1125.

Fig. 17 *Octacolpopites brevicolpa* sp. nov., polar compression ; long. diam. 33 micr. ; sexine thick ; surface finely granular-punctate, very slight gradation of the ornamentation from the periphery to the central region ; octacolpate, colpae short and narrow ; sample no. VD 14 ; phot. ser. no. 5910 ; x1125.

PLATE 2

Fig. 18 *Monocolpopites spinosa* sp. nov., equatorial compression ; long. axis 42 micr. ; spinose, spines short, body granular ; monocolpate, colpus not very expressive, recognisable on focus change ; may be related to *Araceae* ; sample no. VD 31 ; phot. ser. no. 6067 ; x1125.

Fig. 19 *Monocolpopites striaei* sp. nov., equat. compression ; long. axis 46 micr. ; surface characteristically ornamented with converging fine parallel striations ; monocolpate, colpus narrow ; sample no. VD 91 ; phot. ser. no 6046 ; x1125.

Fig. 20 *Microreticulatipites intecta* gen. et. sp. nov., long. diam. 50 micr., intectate ; surface punctate-reticulate, lumina larger than muri ; ? acolporate or monocolpate (? colpus peripheral) ; may be related to *Nelumbiaceae* ; sample no. VD 5 ; phot. ser. no. 6057 ; x1125.

Fig. 21 *Colocasioideaepites longispina* Biswas, oblique polar compression ; long. diam. (without spines) 54 micr. ; spinose, spines uniformly distributed, tapering, on av. 6-7 micr. long ; surface exine minutely granular ; sample no. VD 31 ; phot. ser. no. 6073 ; x1125.

Fig. 22 *Colocasioideaepites brevispina* Biswas, oblique equatorial compression ; long. diam. 44 micr. (without spines) ; spines short, characteristically very broad at the base, slightly curved sides with sudden termination to a point, densely packed ; sample no. VD 14 ; phot. ser. no. 5909 ; x1125.

Fig. 23 *Microforaminifera*, long. axis 77 micr. ; related to ? *Bolivina* ; sample no. VD 105 ; phot. ser. no. 5983 ; x240.

Fig. 24 *Microforaminifera*, long. axis 94 micr. ; related to ? *Gumbelina/Textularia* ; sample no. VD 105 ; phot. ser. no 5976 ; x240.

Fig. 25 *Hystrichosphaeridium scaffoldi* sp. nov., long. diam. of the body 50 micr. ; no platy structure of the body seen, neither any opening ; processes arranged in radiating pattern, of almost uniform length (16-18 micr. long), tips of the processes branched—bifurcated, trifurcated, conjoined with one another to form a scaffolding structure ; sample no. VD 29 ; phot. ser. no. 6017 ; x240.

Fig. 26 *Hystrichosphaeridium sylheti* sp. nov., long. diam. of the body 55 micr, body concentrically layered, no platy structure, neither any opening nor any special coaxial pair of opposite processes ; processes radial in arrangement (on av. 10-12 micr. long), almost straight ; tips simple (unbranched) ; sample no. VD 29 ; phot. ser. no. 5964 ; x845.

PLATE 3

Fig. 27 *Leiotriletes dwarfi* sp. nov., proximal view ; long. axis 31 micr., margin of the grain slightly folded and appears thicker (on two sides), surface smooth ; trilete rays medium in extension ; sample no. VD 152 ; phot. ser. no. 6267 ; x1125.

Fig. 28 *Acolporipites spinulosa* gen. et. sp. nov., body a bit dark ; long. diam. 23 micr. ; surface spinulose ; a triangular peripheral splitted opening—? germinal aperture ; sample no. VD 130 ; phot. ser. no. 6215 ; x1125.

Fig. 29 *Ginkgopites dubia* gen. et. sp. nov., equat. compression ; long. axis 36 micr. ; psilate ; monocolpate, wide opening of the colpus narrowing towards the poles ; shows similarity with the pollen of *Ginkgo* ; sample no. VD 128 ; phot. ser. no. 6207a ; x1125.

Fig. 30 *Tricolporipites dicoti* sp. nov., equat. compression ; long. axis 20 micr. ; exine 1-2 micr. wide ; psilate ; tricolporate, prominent three pores on the equatorial region of the colpae ; sample no. VD 145 ; phot. ser. no. 6246 ; x1125.

Fig. 31 *Monocolpopites broadcolpusi* sp. nov., equat. compression ; long. axis 19 micr. ; psilate ; monocolpate, colpus thick and wide ; sample no. VD 140 ; phot. ser. no. 6227 ; x1125.

Fig. 32 *Hystrichosphaeridium/Dinoflagellate sp.*, long. diam. of the body 62 micr. ; ?presence of platy structure ; processes radial in distribution, infrequent, on average 16 micr. long., tips branched—mainly bifurcated, rarely trifurcated ; sample no. VD 140 ; phot. ser. no. 6230 ; x240.

Fig. 33 *Tricolpopites sp.*, polar compression ; long. diam. 14 micr ; margin thick ; psilate ; tricolpate, colpae shallow ; sample no. VD 152 ; phot. ser. no. 6264 ; x1125.

Fig 34 *Simsangia trispinosa* gen. et. sp. nov., body deltoid ; long. axis of the body 22 micr. ; three spines (120° apart) at three angular margins, spines on av. 6-8 micr long ; no biologic affinity as yet known ; may be a *Hystrichosphaerid* from the resemblance with *H. trispinosum* Eiseneck (Woods 1955) ; sample no. VD 140 ; phot. ser. no. 6223 ; x1125.

Fig. 35 *Laevigatosporites kopilia* sp. nov., bean-shaped ; long. axis 55 micr. ; folded margin ; smooth ; monolete ; sample no. VD 152 ; phot. ser. no. 6268 ; x1125.

Fig. 36 *Leiotriletes garoensis* sp. nov., proximal view ; long. axis 43 micr. ; spore coat very thin ; body smooth ; trilete, narrow dehiscent aperture, apertural rays located in the central part of the grain, trilete area almost always accompanied by a linear exinous fold ; sample no. VD 264 ; phot. ser. no 6315 ; x1125.

Fig. 37 A different compression (an oblique polar compression) of the same type of grain as that of Fig. 38 below ; long. diam 34 micr. ; polar pair of outgrowths seen ; for other morphological description, see fig. 38 ; sample no VD 253 ; phot. ser. no. 6309 ; x1125.

Fig. 38 Gemmate-syncolpate grain (Meyer 1958), (This species has been described elsewhere as *Lygodium dubia* Biswas, which is in course of publication) ; polar compression ; long. diam. 34 micr. ; surface characteristically ornamented with various-sized spherical outgrowths or tubercles, of which three conspicuously larger pairs are located at about 120° apart from one another on the equatorial margin of the grain ; one larger pair of such tubercles is also seen near the polar region of some grains (but they are not always seen) ; there are all sorts of small-size tubercles in between ; syncolpate ; colpae not expressive due to crowding ornamentation but pass through the equatorial pairs of spherical outgrowths ;

controversies may be raised regarding the exact nature of the germinal aperture of these grains and consequently, regarding their exact affiliation to spores or pollen, because the germinal apertures that are being interpreted as colpae, may also be doubted as long trilete rays extending to the angular magins of the grains and in the latter case, the grains may be affiliated to pteridophytic spores, many of which have this kind of tubercles-bearing ornamentation ; sample no. VD 253 ; phot. ser. no. 6306 ; x1125.

Fig. 39 Same as above but with the presence of oblique polar pair of larger tubercles (out of focus in the photograph) ; long. diam. 34 micr. ; sample no. VD 253 ; phot. ser. no. 6305 ; x1125.

Fig 40 *Polypodiaceaesporites tuberculensis* gen. et. sp. nov., bean-shaped ; distal view ; long. axis 44 micr. ; perispore membrane ornamented with medium-size tubercles, tubercles infrequent, rare in the germ. apertural area ; monolete, lete not visible in this particular grain ; sample no. VD 289 ; phot. ser. no. 6364 ; x1125.

Fig. 41 *Schizaeaceaesporites knoxi* gen. et. sp. nov., distal view ; long. axis 47 micr ; characteristically ornamented with moderately thick parallel converging rib-like structures, ribs on av. 2 micr. thick, inter-rib area large ; a loop-like fold in the apertural region ; trilete not visible ; most probably related to the genus *Aneimia* ; may also belong to the spores of *Parkeriaceae* ; sample no. VD 332 ; phot. ser. no. 6368 ; x1125.

PLATE 4

Fig. 42 *Tetradopites granularis* sp. nov., a clustre of three grains visible on upper surface ; long. diam. 35 micr. ; individual grains 20-21 micrs. long ; surface finely granular ; exact nature of germinal aperture of the grains is not clear ; exinous foldings within the grain simulating to the appearance of colpae (tricolpate) ; sample no. VD 253 ; phot. ser. no. 6293 ; x1125.

Fig. 43 *Tricolporipites minima* sp. nov., polar compression ; long. diam. 17 micr. ; surface very finely granulose ; tricolporate, colpae thin with marginal small pores ; sample no. VD 289 ; phot. ser. no. 6356 ; x1125.

Fig. 44 *Tricolpopites prolati* sp. nov., equat. compression ; long. diam. 19 micr. ; surface more or less smooth ; tricolpate, colpae thick and straight, extend from pole to pole, no pores visible ; sample no. VD 289 ; phot. ser. no. 6363 ; x1125.

Fig. 45 *Tricolpopites shorti* sp. nov., equat. compression ; long. diam. 18 micr. ; surface rough ; tricolpate, colpae comparatively thin, do not extend from pole to pole ; sample no. VD 289 ; phot. ser. no. 6354 ; x1125.

Fig. 46 *Bauhinia burdwanensis* Biswas, equat. compression ; long. diam. 36 micr. ; surface characteristically ornamented with intersecting two parallel sets of fine striations ; tricolpate, colpae thin and broad, pole to pole extension ; sample no. VD 253 ; phot. ser. no. 6296 ; x1125.

Fig. 47 *Spinosopites acolporata* gen et. sp. nov., long. diam. 36 micr. (without spines) ; spines broad-based, straight sides, pointed, not very frequent ; no germinal aperture visible, sometimes marginal colpus suspected ; may be related to *Araceae* ; sample no. VD 203 ; phot. ser. no. 6273 ; x1125.

Fig. 48 *Tricolpopites spinosa* sp. nov., oblique equat. compression ; long. diam. (without spines) 44 micr. ; spines medium-based, more or less obtuse termination, infrequent ; tricolpate ; sample no. VD 203 ; phot. ser. no. 6272 ; x1125.

Fig. 49 *Coniferipites garoensis* sp. nov., two-winged pollen ; ventral view ; total equat. length of the grain 56 micr. ; tube-cell larger than the bladders both in equatorial and polar length, impalpably granular ; bladders ear-shaped, attached with the tube-cell throughout its vertical length, parallel to the lateral contour of the tube-cell and about 6-8 micr. apart from each other, irregularly reticulate ; may be related to *Picea* ; sample no. VD 354 ; phot. ser. no. 6537 ; x845.

Fig. 50 *Fungus striata* sp. nov., uniserial, double-chambered ; long. diam. 52 micr. ; characteristically ornamented with converging parallel striations on both sides of the median septum ; sample no. VD 335 ; phot. ser. no. 6408 ; x1125.

Fig. 51 *Tricolpopites granulosa* sp. nov., polar compression ; long. diam. 26 micr. ; surface dense granular to slightly spinulose ; tricolpate, colpal furrow extending right up to the pole ; sample no. VD 348 ; phot. ser. no. 6516 ; x1125.

Fig. 52 *Coniferipites abiesimilis* sp. nov., two-winged pollen ; lateral dorsal view ; total equat. length 64 micr. ; tube-cell much larger than the bladders in equat. length, granular-reticulate ; crest slightly thickened ; bladders low in orientation, attached with the tube-cell by less than half of its equat. length, reticulate ; may be related to the genus *Abies* ; sample no. VD 302 ; phot. ser. no. 6456 ; x845.

Fig. 53 *Ceratopteris macrocostata* Biswas, proximal view ; long. axis 72 micr. ; ornamented with two sets of intersecting parallel ribs ; ribs moderate, inter-rib area much wider ; exine smooth ; trilete prominent, do not extend to the angular region ; may be compared with the spore of the genus *Ceratopteris* (Kuyl et al 1955, Meyer 1958) ; sample no. VD 301 ; phot. ser. no. 6465 ; x1125.

PLATE 5

Fig. 54 *Schizaeaceaesporites/Parkeriaceaesporites* sp., oblique proximal view ; long. axis 57 micr ; ornamented with two sets of intersecting parallel ribs, ribs appreciably thick, inter-rib area narrowed, exine smooth ; trilete obscured ; may be related to *Aneimia/Ceratopteris* ; sample no. VD 342 ; phot. ser. no 6496 ; x1125.

Fig. 55 *Tricolpopites radiistriaei* sp. nov., polar compression ; long. diam. 61 micr., quite large in size ; characteristically ornamented with radiating fine striae ; tricolpate, colpae extending to the poles ; sample no. VD 347 ; phot. ser. no. 6506 ; x1125.

Fig. 56 *Triporipites crescentipora* sp. nov., polar compression ; long. diam. 32 micr. ; exine slightly thick, psilate ; triporate, pores crescent shaped, located about 120° apart, margins of the pores thickened ; may be related to *Betulaceae* ; sample no. VD 347 ; phot. ser. no. 6511 ; x1125.

Fig. 57 *Densexinosporites minuta* gen. et. sp. nov., proximal view ; long. axis 22 micr. ; presence of a 2-3 micr. dense girdle ; labiate trilete, trilete scars limited within the central body ; may have affinity with bryophytic spore ; sample no VD 336 ; phot. ser. no. 6431 ; x1125.

Fig. 58 *Polygonaceaepites zonoides* gen. et. sp. nov., equat. compression ; long. diam. 34 micr. ; body zoned, outward portion appears like a flange which becomes appreciably wider near the poles, a few discrete radiating striae mark the flange, otherwise more granular-reticulate than the main body ; tricolpate, colpae extend from pole to pole (outlimit the inner margin), adjacent ; sample no. VD 300 ; phot. ser. no. 6470 ; x1125.

Fig. 59 Same as Fig. 52, Plate 4 but much larger in total equat. length, also better preservation than the other one ; total equat. length 77 micr. ; bladders more spherical than those of Fig. 52 ; sample no. VD 336 ; phot. ser. no. 6428 ; x240.

Fig. 60 *Coniferipites wilsoni* sp. nov., two-winged pollen ; oblique dorsal view ; only bladders ; 72 micr. (equat. length) x68 micr. (polar length) ; tube-cell could not be identified ; characteristics are with the two large, partially juxtaposed bladders, bladders irregularly reticulate, marginal thickening at places ; sample no. VD 342 ; phot. ser. no. 6495 ; x1125.

Fig. 61 *Coniferipites chattacharai* Biswas, two-winged pollen ; grain broken, short of a bladder ; dorsal view ; on reconstruction, it will measure about 70 micr. ; characteristic features are—tube-cell spherical and appreciably of smaller diameter than that of the bladder and thicker, too ; a few short radial markings from the periphery of the t.c., rough ; bladders oval ; joined with the t.c. by less than half on its equat. length, 6–8 micr. apart from each other, discretely reticulate ; may be related to *Podocarpineae* ; sample no. VD 301 ; phot. ser. no. 6466 x1125.

REFERENCES

1. Biswas, B. (in course of publication) : Stratigraphy of the Mahadeo, Langpar, Cherra and Tura Formations, Assam, India.
2. Cookson, I.C. (1947) : Fossil fungi from Tertiary deposits in the southern hemisphere. Part 1., Proc. Linn. Soc. New South Wales, vol. 72, pp. 207-214.
3. Edwards, W.N. (1922) : An Eocene Microthyriaceous fungus from Mull, Scotland. Trans. Brit. Mycol. Soc., vol. 8, pp. 66-72.
4. Evans, P. (1932) : Tertiary Succession in Assam. Trans. Min. Met. Geol. Inst. India, vol. 27, no. 3.
5. Faegri, K. and J. Iversen (1950) : Text book of modern pollen analysis, Copenhagen.
6. Ghosh, A. M. N. and T. Banerjee (1952) : Post-Jurassic Diastrophic cycles in Assam. Quart. Jour. Geol. Min. Met. Soc. India, Silver Jubilee Volume, vol. 24, no. 1-4, pp. 159-163.
7. Iversen, J. and J. Troels-Smith (1950) : Pollenmorphologiske definitioner og typer. Denmarks Geol. Unders., IV. Raekke, Bd. 3, No. 8, pp. 1-54 (not read in original).
8. Jones, D. J. (1956) : Introduction to Microfossils, New York.
9. Kuyl, O. S., J. Muller and Prof. Dr. H. Th. Waterbolk (1955) : The application of palynology to oil geology with special reference to Western Venezuela. Geologic En Mijnbouw, N. W. S., 17E Jaargang No. 3, pp 49-75, text-fig. 1-8, pls. 1-8.
10. Meyer, B L. (1958) : Palynological Investigation of some samples from Nahorkatiya, Assam. Jour. Pal. Soc. India, vol. 3, Birbal Sahni Memorial number, pp. 156-157, pl. 1 (8 photomicrographs).
11. Naumova, S. N. (1937) : The spores and pollen of the coals of the U.S.S.R. 17th Inter. Geol. Congr. (U.S.S.R.), Abstr. Papers, pp. 60-61.

12. Norem, W.L. (1955) : Pollen, spores and other organic microfossils from the Eocene of Venezuela. Micropaleontology, vol. 1, no. 3, pp. 261-267, text-fig. 1, pls. 1-2 (48 photomicrographs).

13. Idem. (1956) : Tertiary spores and pollen related to paleoclimates and stratigraphy of California, Micropaleontology, vol. 2, no. 4, pp. 313-319, text-fig. 1-3.

14. Potonie, R. and G. Kremp (1954) : Die Gattungen der Palaeozoischen *sporae dispersae* und ihre stratigraphie, Geol. Jb. 69, pp. 111-193 (not read in original).

15. Rao, A.R. and K.P. Vimal (1952) : Tertiary Pollen from Lignites from Palana (Eocene), Bikaner. Proc. Nat. Inst. Sci. India, vol. 18, No. 6, pp. 595-601, pls. 1-2, (36 figs. and 25 photomicrographs).

16. Rao, A.R. 1959 (1958) : Fungal Remains from some Tertiary deposits of India. The Palaeobotanist, Birbal Sahni Inst. of Palaeobotany, vol. 7, no. 1, pp. 43-46, pl. 1 (15 photomicrographs).

17. Sahni, B., R.V. Sitholey and G.S. Puri 1948 (1947) : Palaeobotany in India—6 (Correlation of the Tertiary Succession in Assam by means of microfossils). Jour. Ind. Bot. Soc., vol. 26, no. 4, pp. 262-263, pls. 1-4 (51 camera lucida drawings).

18. Schoff, J., L R. Wilson and R. Bentall (1944) : An annotated synopsis of Paleozoic spores and the definitions of generic groups. Illinois Geol. Surv. Rep. of Investigations no 91, pp. 7-73.

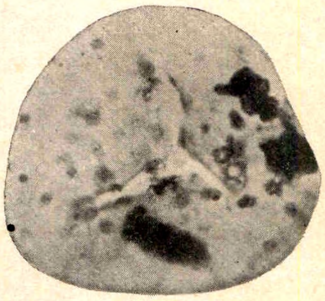
19. Vimal, K. P. (1952) : Spores and Pollen from Tertiary Lignites from Dandot, West Punjab (Pakistan). Proceedings of the Indian Academy of Sciences. Bangalore, vol. 36, Section B. pp. 135-147, pls. V-VIII (42 sketches and 35 photomicrographs).

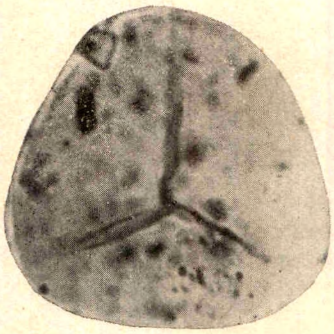
20. Idem. (1953) : Tertiary spores and pollen from Warkali lignites, Travancore. Proc. Ind. Acad. Sci., vol. 38, Sect. B. pp. 195-210, pls. VIII and IX (65 sketches and 40 photomicrographs).

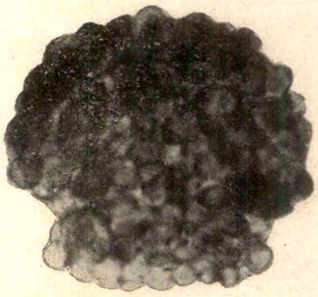
21. Wilson, L.R. (1946) : The correlation of Sedimentary rocks by fossil spores and pollen. Jour Sed. Petrol., vol. 16, no. 3, pp. 110-120.

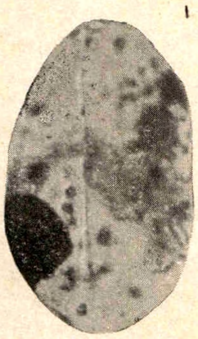
22. Wodehouse, R.P. (1935) : Pollen grains, New York.

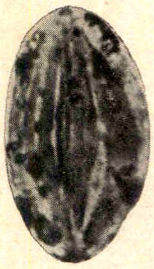
23. Woods, R. D. (1955) : Spores and pollen—A new stratigraphic tool for the oil industry. Micropaleontology, vol. 1, no. 4, pp. 368-375, pl. 1 (15 photomicrographs), text-figs. 1-2.

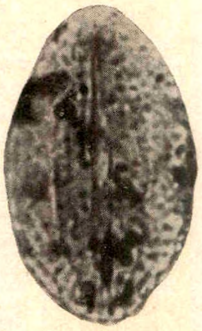

1

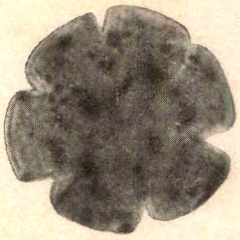

2

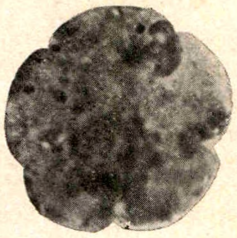

3

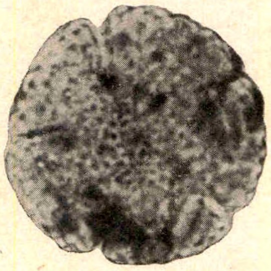

4

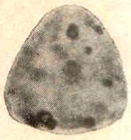

5

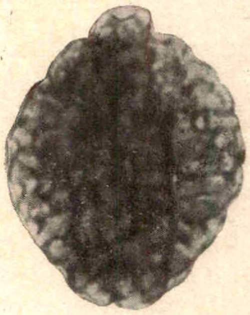

6

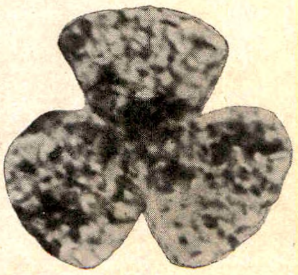

7

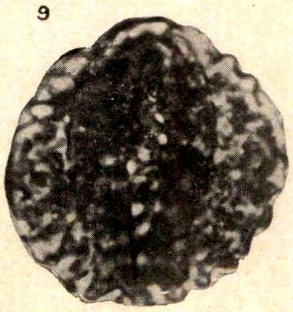

8

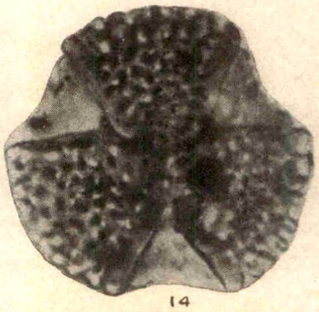

9

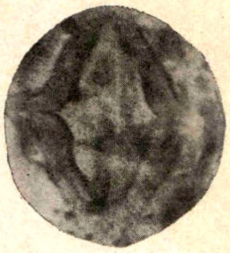

10

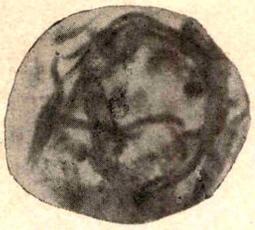

11

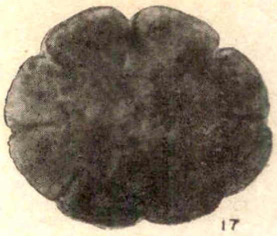

12

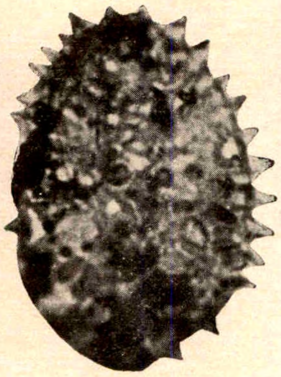

13

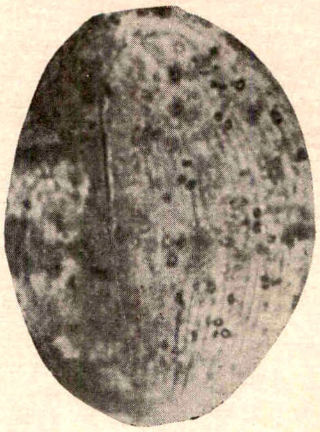

14

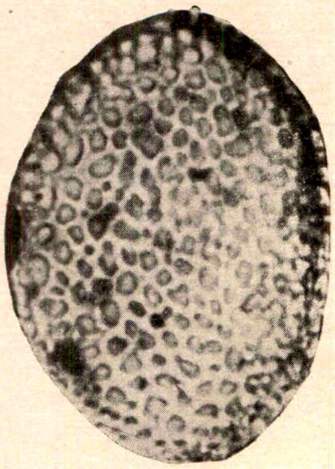

15

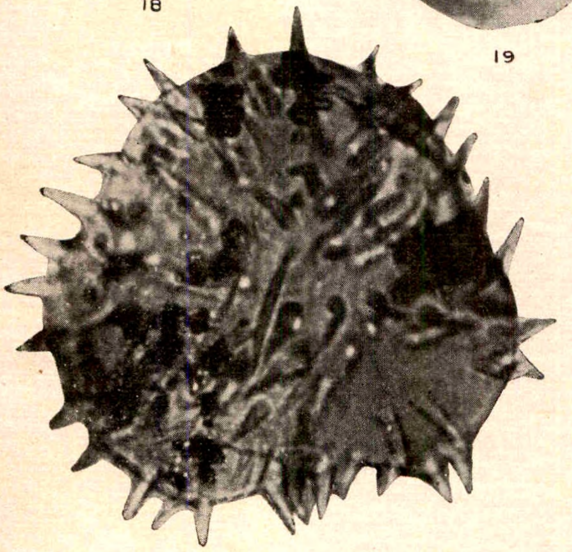

16

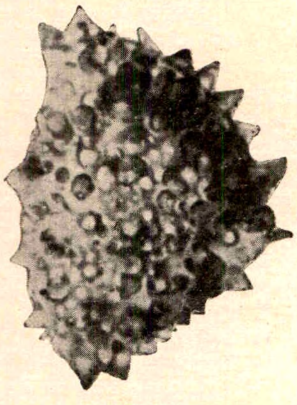

17

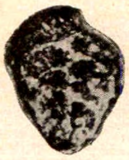

18

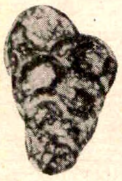

19

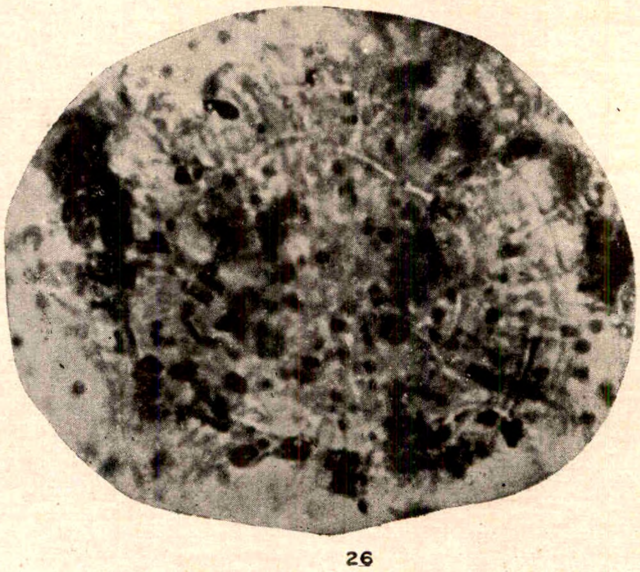

20

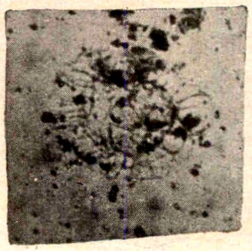

21

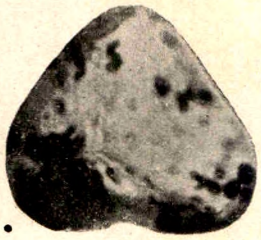

22

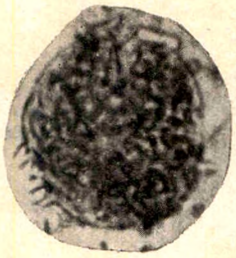

23

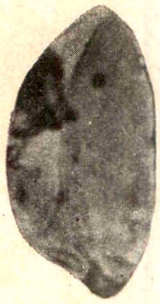

24

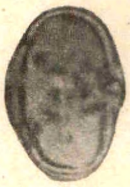

26

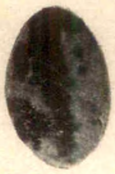

25

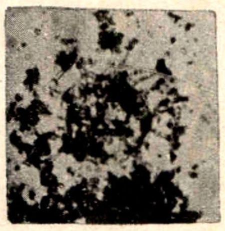

27

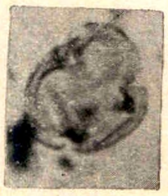

28

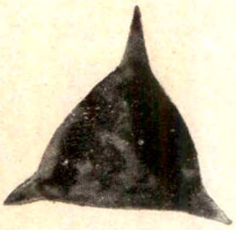

29

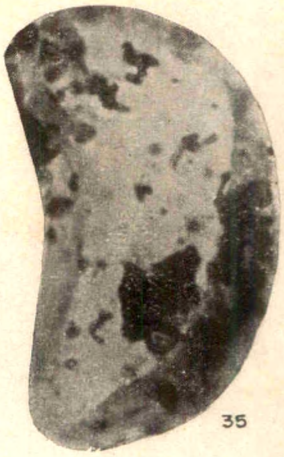

30

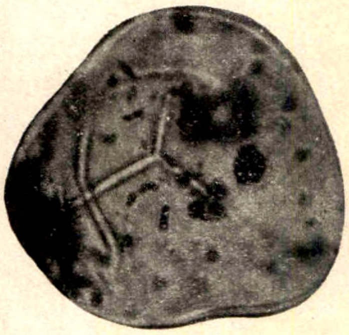

31

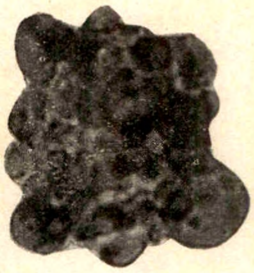

32

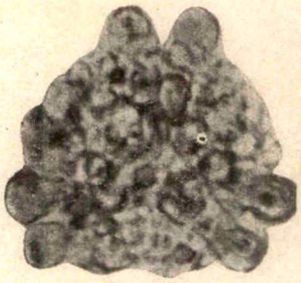

33

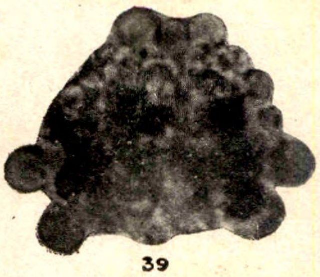

34

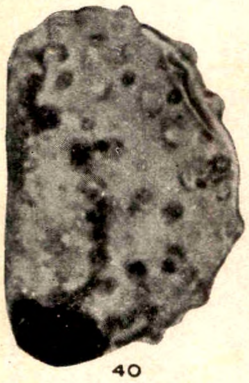

35

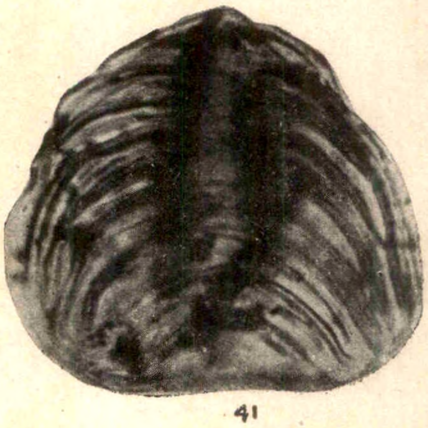

36

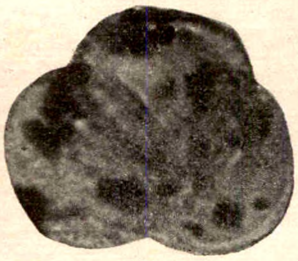

37


38

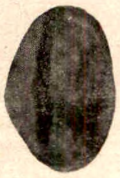

39

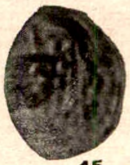

40

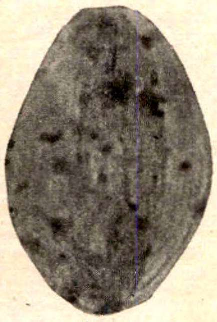

41

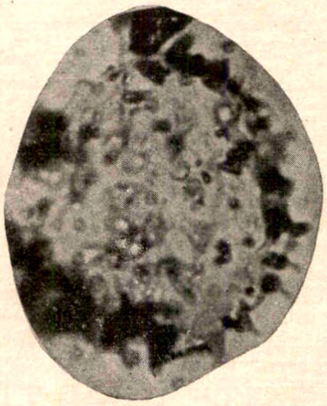

42

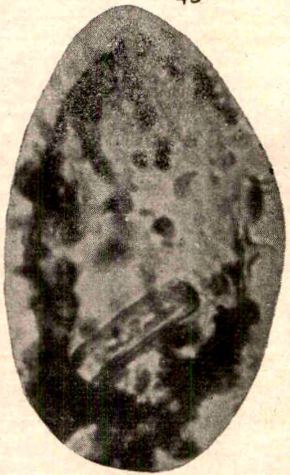
43

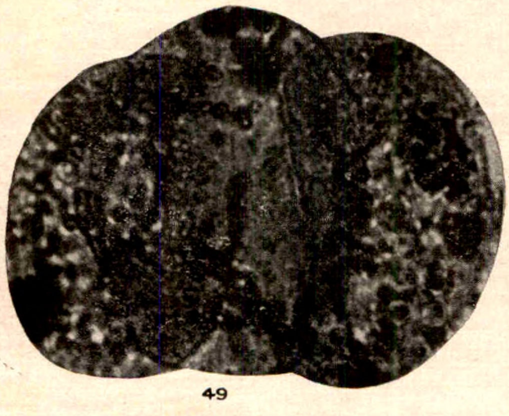

44

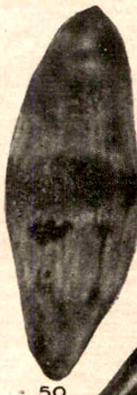

45

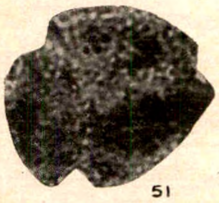

46

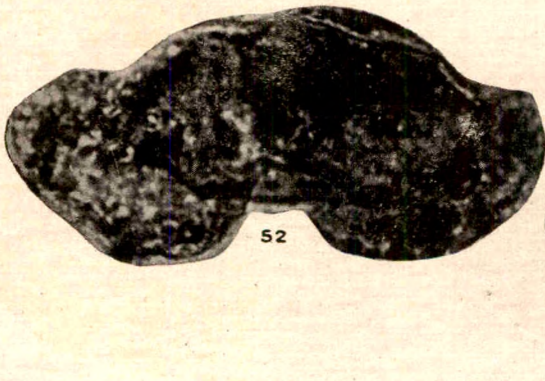

47

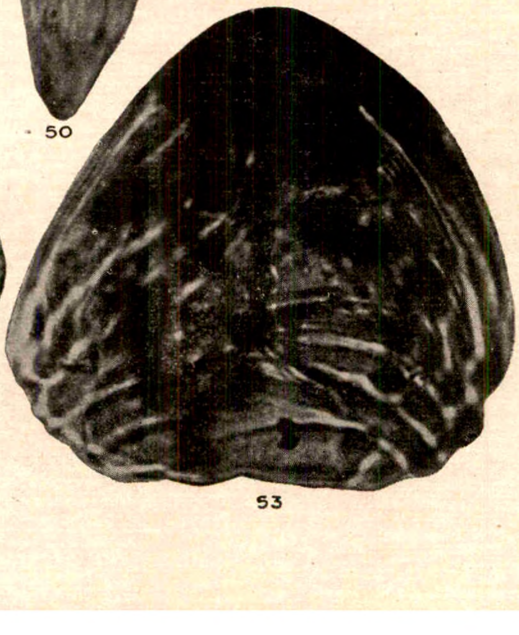

48

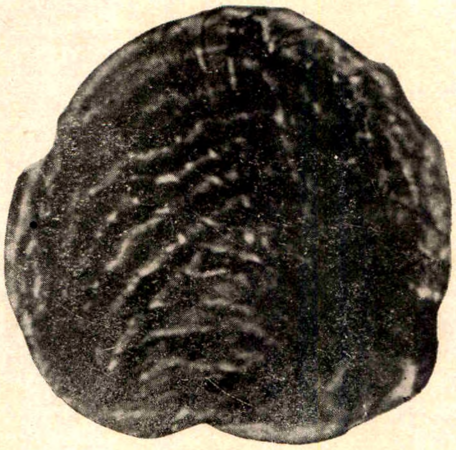

49


50

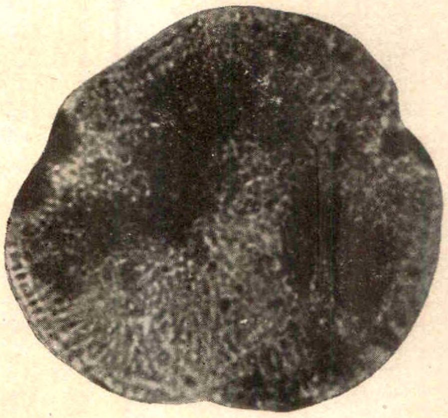

51


52


53

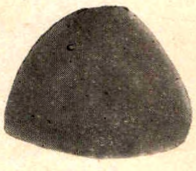


54

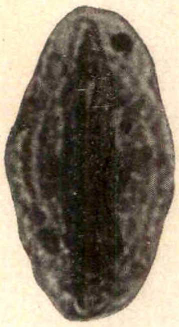


55

56

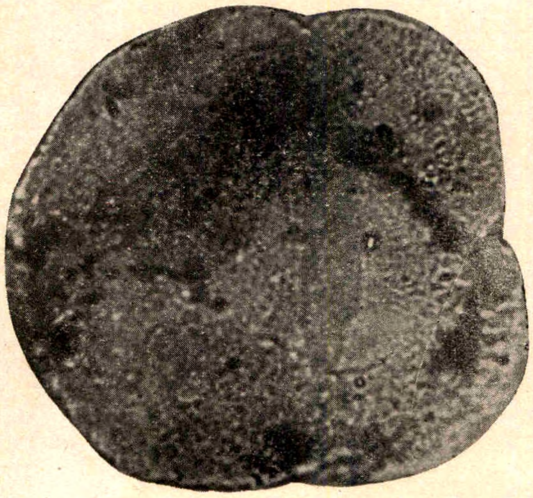


57

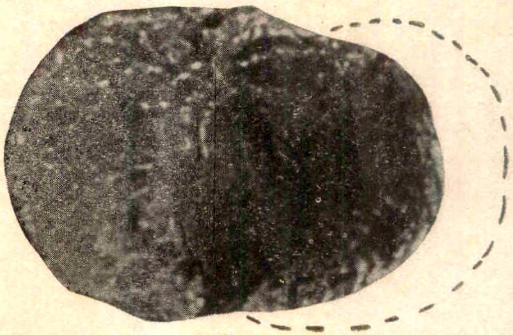


58

59



60



61

CALCUTTA CENTRAL LIBRARY

BULLETIN
OF THE
GEOLOGICAL, MINING & METALLURGICAL
SOCIETY OF INDIA

No. 27] [December, 1962

Assilina from the Eocene Rocks of Garo Hills, Assam*

(Plates 1-6)

BIMAL KUMAR SAMANTA

ABSTRACT

Assilina occurs abundantly in the lower part of the Siju Limestone formation (Middle-Upper Eocene), Garo Hills, Assam. Two new species, Assilina simsongi Samanta and A. subsimsongi Samanta and six new varieties, A. spira taikhimensis Samanta, A. subspira corrugata Samanta, A. subspira rongmukensis Samanta, A. regularia sijuensis Samanta, A. subassamica sijuensis Samanta and A. orientalis garoensis Samanta, along with A spira corrugata de la Harpe, A. regularia (Ghose), A. subassamica Samanta, A. cf. umbilicata (Rutten) and A. sp. are described from the Eocene rocks of Garo Hills, Assam.

The validity of various species of Assilina described from Kirthar rocks of India and Pakistan is discussed. A key to these species is provided. Kirthar forms constitute two different groups of related Assilina : A. spira, A. irregularis, A. papillata, A. regularia, A. simsongi and their corresponding megalospheric forms with lax spire and thick marginal cord; A. exponens, A. mamillata, A. cancellata, A. subcancellata, A. rota, A. cf. umbilicata and A. orientalis with tighter spire and thin marginal cord. It is suggested that the Laki form Assilina sp. A. Nagappa gives rise to A. spira group of forms while another Laki form A. granulosa chhumbiensis Gill gives rise to A. exponens group of forms.

All the species of Assilina reported from Indonesia are found to be represented in the Kirthar rocks of Assam.

INTRODUCTION :

Fossiliferous Eocene rocks are well exposed in different parts of Garo Hills, Assam. Here the Eocene rocks rest directly on the Archaeans and are made up of three rock units namely, Tura Sandstone formation (Lower (?) —Middle Eocene), Siju Limestone formation (Middle-Upper Eocene) and Kopili Shale formation (Upper Eocene) in ascending order. The sequence is conformable.

During geological investigation of this area the author made systematic collection of rocks and fossils from these Eocene formations. In course of the study of these samples it has been found that the foraminiferal genus Assilina occurs abundantly in the lower part of the Siju Limestone formation. Assilina makes its first appearence at the base of the Siju Limestone formation and occurs in full force in its lower half, but is rare or almost absent in higher horizons. The rock containing Assilina varies from loose, soft, marly type to compact, hard, calcitic and dolomitic foraminiferal limestones. Isolated specimens for study can be obtained from the marly bands.

---

*Read before the Society on 16.4.62.

A detailed study of the Assilina-bearing rocks of the present area resulted in the identification of following forms: Assilina spira corrugata de la Harpe, A. spira taikhimensis Samanta n. var., A. subspira corrugata Samanta n. var., A. subspira rongmukensis Samanta n. var., A. simsongi Samanta n. sp., A. subsimsongi Samanta n. sp., A. regularia (Ghose), A. regularia sijuensis Samanta, n. var., A. subassamica Samanta, A.subassamica sijuensis Samanta, n. var., A. orientalis garoensis Samanta, n. var., A. cf. umbilicata (Rutten) and A. sp. The present paper contains a detailed account of these forms together with a general discussion on various species of Assilina described from Kirthar rocks of India and Pakistan. In the synonymy lists only the important references are given. All figured specimens have been deposited in the Museum of the Geology Department, University of Calcutta. Magnifications have been calculated from figures.

ACKNOWLEDGEMENT:

The work was carried out in the Geological Laboratory, Calcutta University under the guidance of Professor N. N. Chatterjee, Head of the Department of Geology, Calcutta University. The author is also grateful to B. K. Ghose, Lecturer, Indian Institute of Technology, Kharagpur for valuable discussion on assilines reported from Khasi Hills, Assam.

PREVIOUS RECORD OF ASSILINES IN THE KIRTHAR ROCKS OF INDIA & PAKISTAN:

Assilina-limestones belonging to Kirthar Series are quite well developed in India and Pakistan. They have been reported from Kutch, Surat-Broach area, Western Pakistan and Assam.

In 1840, J. de C. Sowerby described Assilina (Nummularia) exponens from Kutch and since then other workers have reported both A. exponens (Sowerby) and its megalospheric companion A. mamillata (d'Archiac) from this area.

Further south in Surat-Broach area there is also the reported occurrence of A. exponens (Sowerby) in lower part of the Kirthar (Nagappa, 1959).

Western Pakistan, the type area of the Lower Tertiary rocks of the India-Pakistan region has attracted the attention of eminent workers like d'Archiac, Carter etc. and along with other larger foraminifera, Assilina has been described from time to time from this area. D'Archiac and Haime (1853) in their famous work on Nummulitic rocks of India described and illustrated A. exponens (Sowerby), A. mamillata (d'Archiac) and A. spira (de Roissy) along with two Laki forms. Almost at the same time Carter published two important papers (1853, 1861) on Foraminifera in Western India. He described A.irregularis Carter, A. obesa Carter and A. exponens (Sowerby). In his second publication (1861) he agreed to d'Archiac and Haime that A.irregularis Carter is synonymous with A. spira (de Roissy). In 1906 Vredenburg gave an amended classification of the Tertiary system in Sind and divided the Kirthar series into three main groups—Upper, Middle and Lower. He reported A.exponens (Sowerby) from lower and middle Kirthar rocks, A. sufflata Vredenburg from lower part of middle Kirthar and A. spira (de Roissy) from upper part of the middle Kirthar to the lowest subdivision of the upper Kirthar. Vredenburg was of the opinion that A. sufflata (which was not described and illustrated) is related to A.spira and remarked that 'this form has been erroneously referred by Blanford to Carter's A.obesa. The latter is the megalospheric form (A.mamillata) of a gigantic A.exponens, Carter's var. b'. Nuttall in 1926 attempted a detailed study of the larger foraminifera of Kirthar Series of Western India and described and illustrated A. exponens (Sowerby) and A. mamillata (d'Archiac) from lower Kirthar and lower part of middle Kirthar and A. cancellata Nuttall, A. subcancellata Nuttall, A. papillata Nuttall, A. subpapillata Nuttall and A. spira (de Roissy) from upper part of middle Kirthar. Nuttall, too, opined that Carter's forms—A. irregularis and A. obesa are synonymous with A. spira (de Roissy) and A. mamillata (d'Archiac) respectively. He remarked that A. sufflata Vredenburg is possibly his new form A. papillata. Nuttall did not study the Upper Kirthar rocks and in 1940 L.M. Davies reported A. papillata Nuttall, A. irregularis Carter and A. rota Davies from the Upper Kirthar beds of North-west India. Davies was of the opinion that both A. irregularis Carter and A. papillata Nuttall are valid species. Also A. spira, according to him, occures in India. Eames (1952) recognised the following forms in the Kirthar beds of Western Pakistan and Western India—A. cancellata Nuttall and its megalospheric form A. subancellata Nuttall, A. exponens (Sowerby) and its megalospheric form A. mamillata (d'Archiac), A. rota Davies, A. irregularis Carter and its megalospheric form A. subpapillata Nuttall. He considered A. papillata Nuttall to be synonymous with A. irregularis Carter. Nagappa (1959) regarded A. papillata Nuttall, A. rota Davies, A. exponens (Sowerby) and A. cancellata Nuttall only as valid species occurring in Kirthar series.

In Assam, the Assilina-bearing beds are quite well developed along the southern fringe of the Shillong Plateau. But Assilina, as also other larger foraminifera, has not been properly studied previously from this area. D'Archiac and Haime (1853) reported A. spira (de Roissy) from Sylhet, Assam. P. N. Mukherjee (West, 1949, p. 20) also mentioned its presence in Jaintia Hills. Sale and Evans (1940) reported A. exponens, A. papillata and A. subpapillata from Jaintia series. Davies (1940) recorded A. papillata Nuttall in Siju rocks, Garo Hills. Wilson and Metre (1953) reported it from Prang stage (Middle-Upper Eocene), Central Assam. A. M. N. Ghose (1459) reported the abundance of Assilina in the Kirthar rocks of Assam. He did not make any study of these fossils. Nagappa (1956) recorded A. papillata Nuttall, A. subpapillata Nuttall, A. cancellata Nuttall and A. subcancellata Nuttall from the Prang stage. According to Nagappa (1959) Assilina appeared in Assam for the first time in Middle Eocene rocks and became extinct, as in other parts of India and adjacent countries, well before the end of Eocene. B. K. Ghosh (1959) worked in the Therriaghat area and recorded several new forms such as A. subspinosa Davies var. megacamerata Ghose, A. papillata Nuttall var. regularia Ghose and A. cherrapunjiensis Ghose. No description or illustration of any of these assilines from Assam has been provided by these authors. The report of A. subspinosa var. megacamerata Ghose from Assam is rather contradictory. A. subspinosa has been reported previously only from Laki (Lower Eocene) series. And as mentioned above, in Assam, Assilina appears only during the Kirthar time (Nagappa, 1959). Ghose's report lose much of its importance as he did not mention the stratigraphical horizons from which the samples were collected. Samanta (1961) described and figured two new species, *viz.*, A. assamica Samanta and A. subassamica Samanta from the Siju rocks (Middle-Upper Eocene), Garo Hills. But A. assamica Samanta was found to be synonymous with A. papillata var. regularia Ghose (personal communication with Ghose). So the name was changed to A. regularia (Ghose) (Samanta 1962). In the preliminary report Samanta (1962) mentioned the presence of A. exponens (Sowerby) and A. mamillata (d'Archiac) in Assam along with forms reported in this paper. But a detailed study reveals that these two well known Kirthar forms do not occur in this area. The absence of these widely distributed Kirthar forms in the present area may be accounted for the much late appearence (not before the upper part of middle Kirthar) of Assilina in Assam.

Tipper (1911) and Gee (1926) recorded A. granulosa (d'Archiac) a Laki form from Andaman Islands. According to Nagappa (1959) "his figure (Gee, 1926, pl 14, fig. 4) indicates that it is probably not Assilina granulosa but a form more closely related to the well known Kirthar species Assilina papillata". But this form with well developed ridges along the radial sutures and also along the spiral sutures in the outer whorls which open rather rapidly shows its closest relationship to A. spira (de Roissy). It may be pointed out that Nagappa did not recongnise A. spira in India and Pakistan. A more detailed study is required for correct identification of this form which has important bearing on the determination of the age of the rocks of the area. The megalospheric form identified by R. Furon (1941) as A. granulosa (pl.2, fig. 1) from Pondichery, too, requires further study as it also seems to be related to A. spira group of forms.

In this connection it may be pointed out that the reported occurrence of A. granulosa (d'Archiac) and A. leymeriei (d'Archiac & Haime) in Indonesia is not correct. The description and illustration of the so-called A. granulosa (B and A forms) given by Doornink (1932) clearly show that they are A. spira (de Roissy) (Doornink, pl. x, fig. 1) and its megalospheric companion, A. subspira de la Harpe (Doornink, pl. ix, fig. 18, pl. x, Fig. 2). These Indonesian forms are characterised in having a loosely coiled spire and prominent marginal cord and are identical with forms identified as A. spira corrugata de la Harpe and A. subspira corrugata Samanta from Assam. It is also interesting to note that the other two Indonesian assilines, A. umbilicata (Rutten) and A. orientalis Douville are found to be represented in Kirthar rocks in Assam. Moreover, the group of specimens described by Dr. Caudri (1934) as A. aff. exponens-granulosa from Indonesia belongs to A. spira group of forms and seems to be identical with Assam assilines described here as A. regularia and A. regularia sijuensis.

CLASSIFICATION OF KIRTHAR ASSILINES :

From a study of the previous reports it is seen that opinions differ greatly as regards to the validity of Assilina irregularis Carter and Assilina papillata Nuttall and also about the occurrence of Assilina spira (de Roissy) in India and Pakistan. Although later workers like Eames and Nagappa did not recognise A. spira in Kirthar rocks there is no doubt about the presence of A. spira corrugata de la Harpe in India and adjacent countries and in fact, it is widely distributed in middle and upper Kirthar rocks of this region. Also, at the present state of knowledge both A. irregularis and A. papillata can be retained as valid species. Both these species differ from A. spira (de Roissy) in being evolute and in having irregular whorl walls and chamber partitions. Again, A. irregularis differs from A. papillata in its greater average size, more prominent marginal cord, external ornamentation and in having tapering chambers in transverse sections. A. obesa Carter is synonymous with A. mamillata (d' Archiac) and A. sufflata Vredenburg should be suppressed as it has never been described and illustrated. Thus Assilina is represented in the Kirthar rocks of India and Pakistan by the following forms :

A. spira corrugata de la Harpe and its megalospheric form A. subspira corrugata Samanta, A. spira taikhimensis Samanta, A. subspira rongmukensis Samanta, A. irregularis Carter, A. papillata Nuttall and its megalospheric form A. subpapillata Nuttall, A. regularia (Ghose) and its megalospheric form A. subassamica Samanta, A. regularia sijuensis Samanta and its megalospheric form A. subassamica sijuensis Samanta, A. simsongi Samanta and its megalospheric form A. subsimsongi Samanta, A. exponens (Sowerby) and its megalospheric form A. mamillata (d'Archiac),* A. cancellata Nuttall and its megalospheric form A. subcancellata Nuttall, A. rota Davies, A. cf. umbilicata and A. orientalis garoensis Samanta.

These forms are much variable in characters and some gradations may exist between closely related forms. But from careful observations they can be separated from one another on the basis of following characters mainly :

Rate of opening of the spire.
Thickness of the marginal cord.
Degree of envelopment of the spiral sheet.
External appearance.

Following is a key to these Kirthar forms :

I. Group of A. spira : Spire lax : marginal cord thick :

A. Large : Spiral sutures raised : in transverse sections chambers tapering in shape : marginal cord very prominent :

1. Form semi-involute : whorl walls and chamber partitions much regular : thickness practically same at the central part as at the periphery : ... A. spira corrugata & its megalospheric form
2. Form semi-involute : whorl walls and chamber partitions much regular : central part thickened ... A. spira taikhimensis.

---

* According to Ziegler (1960) A. mamillata (d Archiac) is not the megalospheric companion of A.exponens (Sowerby). He described under A. mamillata (d'Archiac) both microspheric and megalospheric forms which, according to him, can be distinguished specifically from A exponens (Sowerby) and its megalospheric companion.

3. Form evolute: whorl walls and chamber partitions irregular: central part depressed: ... A. irregularis.

B. Small: spiral sutures depressed or flush with the surface: in transverse sections chambers inflated away from the whorl junctions: marginal cord less prominent:

1. Form semi-involute: whorl walls and chamber partitions regular: margin rounded: ... A. regularia & its megalospheric form
2. Form semi-involute: whorl walls and chamber partitions regular: margin angular: ...A. regularia sijuensis & its megalospheric form
3. Form evolute: whorl walls and chamber partitions irregular: margin rounded: ...A. papillata & its megalospheric form

C. Form semi-involute: highly irregular in characters: .. A. simsongi & its megalospheric form

II. Group of A. exponens: spire tight: marginal cord thin:

A. Form semi-involute:

(a) Large: surface with raised septal sutures: chambers much higher than long:

1. Surface markings not prominent: tightly coiled: ... A. cancellata & its megalospheric form
2. Smaller in average size: surface markings prominent: less tightly coiled: ... A. exponens & its megalospheric form

(b) Small: surface papillate: chambers with considerable length:

1. Central part thickened: margin rounded: ... A. rota.
2. Central part depressed: margin angular: ... A. cf. umbilicata.

B. Form involute: small: surface granulated: ... A. orientalis garoensis.

Thus the Kirthar species of Assilina could be subdivided on the basis of rate of opening of the spire and thickness of marginal cord into two broad groups; —the first comprised of species with loosely coiled spire and thick marginal cord: A. spira, A. irregularis, A. papillata, A. regularia, A. simsongi and their corresponding megalospheric forms; and the second including the species with tighter spire and thin marginal cord: A. exponens, A. mamillata, A. cancellata, A. subcancellata, A. rota, A.cf. umbilicata and A. orientalis. The forms of the first group are operculine in characters while those of the second group are more nummulitic in characters.

In Laki series also the assilines are similarly separable into two broad groups: Assilina sp. A. Nagappa differs from A. granulosa, A. daviesi, A. laminosa and their corresponding megalospheric forms in having prominent marginal cord and rapid rate of opening of the spire. So it can be assumed that Nagappa's form Assilina sp. A. which appeared late in the Laki series gives rise to A. spira group of forms in Kirthar time, while A. exponens group of forms probably originated from such form as A. granulosa chhumbiensis Gill.

VALIDITY OF THE GENUS ASSILINA D'ORBIGNY:

The genus Assilina was erected by d'Orbigny in 1826; since then there has been constant difference in opinion regarding the validity of this genus. The main issue was that whether the mere absence of alar prolongations of chambers in Assilina is sufficient to distinguish it generically from Nummulites. A number of workers retained it as a valid genus, but a group of others considered it to be a subgenus while author like Cole (1960) opined that separation even in subgeneric level is not admissible. But uptil now there is no recorded evidence of complete gradation in a single species from Assilina to Nummulites and no confusion has ever arisen in distinguishing the one genus from the other. In the present report, therefore, Assilina has been treated as a valid genus.

Moreover, as pointed out by H. Schaub (1961) the introduction of the new generic name Planocamerinoides Cole in place of Assilina is not valid.

PROVENANCE OF MATERIAL:

The samples for the present study were collected from four different localities in Garo Hills, Assam. The localities are as follows:

(a) Siju area:

Siju Songmong village (90°42′ E, 25°22′ N); Loc. R (Rongmuk Thainang village): two furlongs SSW of Siju Songmong village:—in Simsong river section.

Taikhimgithin village (90°41′ E, 25°21′ N) Loc. T (Taikhimgithim): in Simsong river section.

(b) Daranggiri area:

Darang Era Aning Songgital village (90°45′ E, 25°27′ N) Loc. D (Daranggiri): one and one-half furlongs south of Darang village:—in road section.

(c) Tura area:

Sonkiniggiri village (90°16′ E, 25°23′ N) Loc. S (Sonkiniggiri): two furlongs NNW of Sonkiniggiri-village;—in Norang river section.

DESCRIPTION OF SPECIES

Family **Nummulitidae**

Genus **Assilina d'Orbigny, 1826**

Assilina spira corrugata de la Harpe

(Pl. 1, figs. 1-4, 6-9, 11-15)

1853. Nummulites spira de Roissy. d'Archiac and Haime. Monographic des Nummulites, p. 155, pl. xi, fig 5.

1926. Assilina spira var. corrugata de la Harpe, n. var. A.M. Kir. Foldtani Intezt. Evkon, vol. 27, p.93.

1926. Assilina spira de Roissy. Nuttall, Geol. Sur. India Rec., Vol. 59, p.143, pl. 6, figs. 8-9.

Test large, compressed, sides parallel with rounded cord-like margin. Ornamentation takes the form of prominent ridges along the spiral sutures with small radial bars in between them indicating the septal sutures ; few slightly raised papillae are always present over the chamber spaces. Polar region may be smooth and slightly depressed.

Equatorial sections show a loosely coiled spire with the outer whorls opening much more rapidly than the inner ones. Chambers higher than long. Chamber walls straight and radial with a sharp curvature at there distal ends.

Form is semi-involute. Transverse sections also show the very prominent marginal cord with well developed pillar structures at the whorl junctions. Chambers in transverse sections much higher than broad and typically tapering in shape.

Occurrence :

Found at localities T (Taikhimgithim) and D (Daranggiri) in Garo Hills, Assam.

Remarks :

This variety as stated by de la Harpe differs from the typical in having ridges along the spiral sutures and also along the radial sutures. Moreover in specimens from Assam few small papillae always occur over the chamber spaces. It is distinguished from other assilines in the present area by its prominent ridges along the spiral sutures, rapid rate of opening of the spire, very prominent marginal cord and tapering chambers in transverse sections.

Figures 6 and 15 in plate 1 show some resemblance with A. irregularis Carter. They represent more evolute forms with irregular whorl walls and chamber partitions.

This form is less variable in its character and can be easily recognised even from its external appearance. It is also widely distributed and has been reported from Europe, Western Pakistan, Assam and Indonesia. In India and adjacent countries A. spira seems to appear rather late in the Middle Eocene times. In this region it occurs in beds younger in age than those in which A. exponens has been recorded.

Measurements of *Assilina spira corrugata*

Dimensions	Specimen shown on pl. 1												
	Fig. 1	Fig. 2	Fig 3	Fig. 4	Fig. 6	Fig. 7	Fig. 8	Fig. 9	Fig. 11	Fig. 12	Fig. 13	Fig . 14	Fig. 15
Diameter ... ... mm	23.0	21.7	18.2+	24.5	19.5	23.2	21.8+	24.5+	21.5	24.6+	24.5	19.5	19.9
Thickness ... ... mm	1.9	...	2.3	...	1.1	...	...	...	1.5	1.4	1.2	1.5	1.2
Whorls ... ... No.	...	...	...	...	...	11½	11¼	12⅓	...	...	...	...	...
Chambers in first volution No.	...	...	...	...	...	7	7	8	...	...	...	...	...
Chambers in one quadrant of final volution ,,	...	..	...	...	...	10	9	13	...	...	...	...	...

Assilina spira taikhimensis Samanta, n. var.

(Pl. 1, figs. 5,10,16)

Test comparatively small, typically with an inflated central part which is surrounded by the thinner peripheral part ; the separation of the elevated part from the rim is rather sharp. The surface of the elevated area is nearly flat. Both sides of the test are covered with small, raised papillae larger towards the central part and arranged along the spiral and septal sutures marking them on the surface.

In transverse sections, semi-involuteness of the form, very prominent marginal cord and tapering chambers with much greater height than breadth in the case of outer whorls are visible. The spire opens slowly and regularly in the inflated part of the test and then the height of the whorls increases abruptly forming the flat rim.

Measurements of *Assilina spira taikhimensis* :

Dimensions		Specimens					
		Pl. 1 Fig. 5	Not illus.	Pl. 1 Fig. 10	Not illus.	Pl. 1 Fig. 16	Not illus.
Diameter	mm.	15.3+	14.5	14.0	13.6+	14.9	15.5
Thickness at centre	mm.	2.4	2.1	—	—	2.0	1.75
Diameter of the inflated central part ...	mm.	5.6	5.8	—	—	4.4	5.5
Thickness	mm.	1.6	1.6	—	—	1.0	1.25
Surface diameter of papillae near the centre	mm.	.200–.300	.200–.300	—	—	—	—
Whorls	numbers	—	—	10	10½	—	—
Chambers in first volution	,,	—	—	6	7	—	—
Chambers in final volution ...	,,	—	—	37	39	—	—

Occurrence :

Found only at locality T (Taikhimgithim) in Garo Hills, Assam.

Remarks :

This variety differs from the species proper in being smaller in size, in having the surface covered with small raised granules and inflated central part. This variety is rare in its occurrence in the present area and so the range of variation of its characters could not be studied. It seems to represent a form transitional between A. spira and A. praespira. It may be mentioned that, uptil now there is no reported occurrence of A. praespira in India.

Assilina subspira corrugata Samanta, n. var.,

(Pl. 2, figs. 1-6, 9-11, 14-17).

This megalospheric form occurs abundantly in the present area associated with A. spira corrugata de la Harpe. Test is much smaller in size. Sutures of the chamber walls show on the surface as raised lines ; spiral sutures in the outer whorls are raised.

Measurements of *Assilina subspira corrugata*

Dimensions		Specimen shown on pl. 2													
		Fig. 1	Fig. 2	Fig. 3	Fig. 4	Fig. 5	Fig. 6	Fig. 9	Fig. 10	Fig. 11	Not illus	Fig. 14	Fig. 15	Fig. 16	
Diameter ...	mm.	10.2	9.7	10.1	9.0	8.7	9.6	7.6	9.3	8.8	7.1	9.1	8.7+	8.6	8.6
Thickness ...	mm.	1.2	1.1	1.0	1.2	1.2	1.4	—	—	—	—	1.0	1.0	0.75	0.9
Diameter of polar boss	mm.	—	—	—	—	0.8	2.0	—	—	—	—	—	—	—	2.2
Embryonic chambers:															
Diameters of initial chamber	µ	—	—	—	—	—	—	375×400	350×450	350×	325×375	300×350	350×475	375×425	—
Diameters of second chamber	µ	—	—	—	—	—	—	200×350	225×400	300×350	250×375	190×35	300×450	—	—
Distance across both chambers	µ	—	—	—	—	—	—	600	575	650	600	500	675	—	—
Whorls ...	number	—	—	—	—	—	—	5⅛	5¾	5½	6¼	—	—	—	—
Chambers in first volution ...	number	—	—	—	—	—	—	5	6	8	6	—	—	—	—
Chambers in final volution	number	—	—	—	—	—	—	28	31	—	—	—	—	—	—
Chambers in all volutions	number	—	—	—	—	—	—	85	about 112	—	—	—	—	—	—

Polar region shows much variation in ornamentation ; sometimes the polar region is flat and smooth while in other cases it is covered with small raised granules which often clustered together to form a small boss at the poles.

Internally the spire is loose but rather regular. Chambers normally higher than long. Chamber walls straight with curvature at their distal ends. The embryonic chambers are bilocular with the initial chamber slightly larger in size than the second chamber ; wall between the embryonic chambers straight or slightly curved backwards.

Transverse section show that the form is semi-involute. Marginal cord well developed. Chambers much higher than broad.

Occurrence :

Found at localities T (Taikhimgithim) and D (Daranggiri) in Garo Hills, Assam.

Remarks :

As in the case of the microspheric form, it is also characterised in having ridges along both spiral and radial sutures; minute granules are also present over the chamber spaces. So the varietal name corrugata is given.

Unlike its microspheric companion A. subspira de la Harpe is rather poorly described and illustrated. In India and adjacent countries only d'Archiac and Haime (1853) recorded the megalospheric companion of A. spira. Nuttall (1926) who reported A. spira from western India, denied the presence of A. subspira there. But this form is widely distributed like its microspheric companion. In Assam it is much more abundant than its microspheric form. As mentioned before it occurs in Indonesia and probably also in Pondicherry and Andaman Islands.

Assilina subspira rongmukensis Samanta, n. var.

(Pl. 2, figs. 7,8,12,13,18)

Test small, flat with a small, shallow depression at the poles ; margin angular. Both the spiral sutures and radial sutures are distinctly raised and the chamber spaces appear as slightly depressed areas covered with fine papillae.

Equatorial sections show marked increase in the height of the outer whorls. Chambers are always higher than long. Chamber walls are nearly straight to slightly curved in the outer whorls. The embryonic chambers are bilocular with a very small circular initial chamber followed by a smaller reniform chamber. The wall separating the embryonic chambers is rather thick. Chambers typically tapering in shape in transverse section. Marginal cord well developed.

Occurrence :

Found only at locality R (Rongmuk Thainang) in Garo Hills, Assam.

Remarks :

This variety differs from A. subspira corrugata Samanta externally in having a smaller and thinner test with small depression at the poles, internally in having much

Measurements of *Assilina subspira rongmukensis*

Dimensions		Specimen shown on pl. 2							
		Fig. 7	Fig. 8	Fig. 12	Not illustrated	Fig. 13	Not illustrated	Fig. 18	Not illustrated
Diameter ...	mm.	6.0	7.5	6.35	6.0	5.2	8.5	6.45	6.1
Thickness ...	mm.	0.68	0.72	—	—	—	—	0.65	0.7
Diameter of polar depression	mm.	0.65	0.5	—	—	—	—	—	0.5
Embryonic chambers :									
Diameter of initial chamber	μ	—	—	175×175	150×190	150×175	175×225	225×225	—
Diameter of second chamber	μ	—	—	125×175	100×190	100×200	125×215	50×200	—
Distance across both chambers	μ	—	—	300	275	275	315	275	—
Whorls ...	number	—	—	5½	5½	5½	6½	—	—
Chambers in first volution	number	—	—	6	6	6	6	—	—
Chambers in final volution	number	—	—	21	—	22	—	—	—
Chambers in all volutions	number	—	—	88	—	83	—	—	—

Measurements of *Assilina simsongi*

Dimensions		Specimen shown on pl. 3										
		Fig. 1	Fig. 2	Fig. 3	Fig. 4	Fig. 5	Fig. 6	Fig. 7	Fig. 8	Fig. 9	Fig. 10	Fig. 11
Diameter	mm	12.4	11.6	9.3	8.5	7.7	13.8	9.1	11.0	10.0	10.5	9.1
Thickness	mm	—	5.5	2.0	2.1	—	—	—	2.2	1.9	2.0	1.5
Whorls	number	—	—	—	—	about 9	11	10	—	—	—	—
Chambers, in first volution	number	—	—	—	—	—	7	about 6		—	—	—
Chambers in final volution	number	—	—	—	—	—	about 28	36	—	—	—	—

smaller embryonic chambers and comparatively thick wall separating them. Shape of the embryonic chambers is also different.

Assilina simsongi Samanta, n. sp.

(Pl. 3, Figs. 1-11)

Test of medium size, irregular, compressed lenticular with broadly rounded to angular and truncated margin. Surface ornamented with slightly raised spiral and radial sutures with small granules over the chamber spaces. Very often the central part of the test considerably depressed; rarely a small central boss occurs.

In equatorial section the spire is typically loose and irregular. Generally it begins with a series of tight whorls, followed by rapidly opening ones and later the spire becomes tighter again. Chambers higher than long. Septa variable. Form semi-involute, irregular with much variation in thickness in different parts of the section. Chambers variable in shape in transverse section. Marginal cord prominent. Pillar structures near the junctions of whorls well developed.

Occurrence :

Found only at locality T (Taikhimgithim) in Garo Hills, Assam.

Remarks :

This species belongs to the same group as A. spira (de Roissy). This semi-involute form with well-developed marginal cord is closely related to A. spira from which it differs in the extreme irregularity of its characters.

Assilina subsimsongi Samanta, n. sp.

(Pl. 2, figs. 19-21, plate 3, fig. 12-15)

Test small, flat with truncated margin ; more or less rectangular in transverse

Measurements of *Assilina subsimsongi*

Dimensions		Specimen shown on						
		Pl. 3 Fig. 12	Pl. 3 Fig 13	Pl. 2 Fig 19	Pl. 3 Fig. 14	Pl. 2 Fig 20	Pl. 3 Fig 15	Pl. 2 Fig. 21
Diameter ...	mm.	8.0	8.5	4.7	7.0	6.1	5.1	5.8
Thickness ...	mm.	1.7	2.2	0.8	—	–	1.3	1.2
Embryonic Chambers:								
Diameters of initial chamber ...	μ	—	—	—	275 × 275	350 × 310	—	—
Diameters of second chamber ...	μ	—	—	—	125 × 275	320 × 310	—	—
Distance across both chambers ...	μ	—	—	—	450	680	—	–
Whorls ...	number	—	—	—	5	3½	—	—
Chambers in first volution ...	number	—	—	—	6	7	—	—
Chambers in final volution ...	number	-	—	—	28	25	—	—
Chambers in all volutions ...	number	—	—	—	—	57	—	—

section. Both spiral and radial sutures prominently raised, few small granules always occur in between them.

Internally the spire is loose and irregular. Chambers higher than long. Chamber walls straight to moderately curved. Embryonic chambers bilocular; both the initial and the second chambers are rudely spherical in shape and almost equal in size. Form semi-involute with prominent pillar structures at the junctions of the whorls. Marginal cord well developed.

Occurrence:

Found only at locality T (Taikhimgithim) in Garo Hills, Assam.

Remarks:

This megalospheric form always occurs in association with A. simsongi Samanta and shows all the characteristics of that species. It is less abundant than its microspheric companion.

Assilina regularia (Ghose)

(Pl. 4, figs. 1-13)

1959. Assilina papillata Nuttall var. regularia Ghose, Science & Culture, Vol. 26, No. 6, p. 376.

1961. Assilina assamica Samanta, Geol. Min. Met. Soc. India, Quart. Jour., Vol. 33, No.2, p. 89, figs. 1-4.

Test large compressed with smooth rounded margin. Sides of the test parallel except in few cases where a small slightly elevated central boss occurs. Surface is completely covered with slightly raised papillae. Spiral sutures depressed or very slightly raised, radial sutures generally show on the surface of the test as faint lines.

Internally the spire is regular with the outer whorls increasing rapidly in height. Chambers higher than long. Chamber walls straight and radial with a sharp recurvature at the distal ends.

Transverse sections show the semi-involuteness of the form, thick marginal cord and occasional pillar structures at the whorl junctions. Chambers are higher than broad and typically inflated away from the whorl junctions.

Occurrence:

Found at localities R (Rongmuk Thainang) and T (Taikhimgithim).

Remarks:

This species is characterised externally by its finely papillate surface and internally by its lax spire, thick marginal cord and semi-involuteness of the whorl walls. It is closely similar to A. papillata Nuttall from which it differs in being semi-involute and in possessing more regular whorl walls and chamber partitions.

Earlier workers have identified this form as A. papillata Nuttall because externally A. papillata and A. regularia are very similar. Nuttall (1926) erected his form A. papillata mainly on external character. He neither described the internal characters properly nor gave adequate illustrations of internal structures. Later Davies (1940) restudied this form and gave sufficient description and illustration of Nuttall's

Measurements of *Assilina regularia*

Dimensions	Specimen shown on Pl. 4														
	Fig 1	Fig. 2	Fig 3	Fig. 4	Fig. 5	Fig. 6	Fig 7	Fig. 8	Fig. 9	Not. illust.	Fig. 10 Left	Fig. 10 right	Fig. 11	Fig. 12	Fig. 13
Diameter mm.	14.6	21	15	19	17	13.6	15.5	14.0	14.3	18.0	16.2	19.6	18.0	15.0	6.0×2 =12.0
Thickness at centre mm.	2.1	2.3	2.3	1.8	1.8	2.1	—	—	—	—	1.5	1.2	1.6	1.3	2.0
Diameter of inflated central part. mm.	—	—	5.9	—	—	4.1	—	—	—	—	—	—	—	—	3.0
Whorls number	—	—	—	—	—	—	about 9	10	10	11	—	—	—	—	—
Chambers in first volution number	—	—	—	—	—	—	6	7	7	7	—	—	—	—	—
Chambers in final volution number	—	—	—	—	—	—	36	25	35	47	—	—	—	—	—

Measurements of *Assilina regularia sijuensis*

Dimensions	Specimen shown on pl. 5												
	Fig. 1	Fig. 2	Fig. 3	Fig. 4	Fig. 5	Fig. 6	Fig. 7	Fig. 8	Not. illust.	Fig. 9	Fig 10	Fig. 11	Fig. 12
Diameter mm.	12.4	14.9	12.8	11.4	9.4	11.5	11.4	9.7	15.6	14.1	12.5	17.1	11.3
Max. thickness mm.	1.7	2.2	2.1	2.1	2.2	—	—	—	—	1.7	1.65	1.8	1.5
Thickness at centre mm.	—	—	—	—	—	—	—	—	—	1.2	1.25	1.15	1.2
Surface diameter of granules near the centre µ	—	—	—	400-500	400-500	—	—	—	—	—	—	—	500
Whorls number	—	—	—	—	—	10½	10½	9½	12	—	—	—	—
Chambers in first volution "	—	—	—	—	—	5	7	7	6	—	—	—	—
Chambers in final volution "	—	—	—	—	—	29	34	30	34	—	—	—	—

A. papillata. From Davies's account it follows clearly that the specimens from Assam differ specifically from A. papillatta Nuttall and Samanta (1961) described it as A. assamica n. sp. Later personal communication with Ghose reveals that his form A. papillata regularia (which has not been described and illustrated) and A. assamica Samanta n. sp. are the same form. So due to priority of the former name the name is changed to A. regularia (Ghose).

Assilina regularia sijuensis Samanta, n. var.

(Pl. 5, figs. 1-12)

Test comparatively small, compressed with shallow central depression and sloping peripheral part, margin angular. The spiral suture is depressed and more distinctly so as the periphery is approached; sutures of the chamber walls show on the surface as raised lines made up of radially arranged small granules. The surface of the test is covered with papillae which are prominent in the polar region and become finer towards the periphery.

Spire regular with the outer whorls opening more rapidly than the inner ones. Chambers higher than long. Chamber walls normally straight and radial, but several have slight curvature at their distal ends.

Transverse sections show the semi-involuteness of the form, rather well developed marginal cord and distinct pillar structures scattered throughout the section but more prominent in the central part.

Occurrence:

Found at localities R (Rongmuk Thainang), D (Daranggiri) and S (Sonkiniggiri) in Garo Hills, Assam.

Remarks:

This variety differs from the species proper in having a smaller test, more tightly wound spire and thinner marginal cord. Also pillars are more prominent in this variety. Margin generally angular.

The presence of this form in Assam is rather interesting in that it shows characters somewhat intermediate between A. spira group and A. exponens group of forms. But in its opening of spire, development of marginal cord and character of chamber walls it is more related to the A. spira group of forms and so has been described here as a variety of A. regularia (Ghose) with which it shows the closest relationship.

Assilina subassamica Samanta

(Pl. 4, figs. 14-16 ; pl. 5, figs. 19-21 ; pl. 6, figs. 1-4).

1961. Assilina subassamica Samanta, Geol. Min. Met. Soc. India, Quart. Jour. Vol. 33, No. 2, p. 90, figs. 5-8.

Test small, compressed with rounded to angular margin. Surface covered with slightly raised papillae, large and concentrated in the central region Spiral sutures normally depressed, sutures of the chamber walls show on the surface as slightly raised lines. Central part of the test is sometimes slightly depressed while in others it is inflated to form a small boss.

Measurements of *Assilina subassamica*

Dimensions		Specimen shown on											
		Pl. 6 Fig. 1	Pl. 6 Fig. 2	Pl. 6 Fig. 3	Pl. 6 Fig. 4	Pl. 4 Fig. 14	Pl. 4 Fig. 15	Pl. 4 Fig. 16	Not illustrated	Pl. 4 Fig. 12	Pl. 5 Fig. 19	Pl. 5 Fig. 20	Pl. 5 Fig. 21
Diameter ...	mm	7.6	7.2	6.8	8.5	7.1	7.0	10.0	6.0	8.2	6.2	5.0	7.9
Thickness ...	mm	1.4	1.3	1.1	1.3	—	—	—	—	—	0.6	0.5	0.9
Diameter of polar boss ...	mm	—	1.5	1.8	1.9	—	—	—	—	—	2.2	1.5	—
Thickness at centre ...	mm	—	1.5	—	1.7	—	—	—	—	0.8	1.1	0.7	—
Embryonic chambers :													
Diam. of initial chamber	μ	—	—	—	—	350×500	300×450	350×400	310×375	—	290×350	210×225	360×360
,, secoud chamber	μ	—	—	—	—	200×400	230×400	225×350	275×375	—	—	—	—
Distance across both chambers	μ	—	—	—	—	575	550	600	600	—	—	—	—
Whorls	number	—	—	—	—	4¼	4¾	6	4½	—	—	—	—
Chambers in first volution	number	—	—	—	—	6	5	7	7	—	—	—	—
,, ,, final volution	number	—	—	—	—	22	22	28	32	—	—	—	—
,, ,, all volutions	number	—	—	—	—	61	74	—	82	—	—	—	—

Spire lax but regular. Embryonic chambers bilocular with the initial chamber always slightly larger in size than the second chamber; the wall separating the embryonic chambers is straight. From semi-involute. Marginal cord well developed. Chambers higher than broad and inflated in transverse sections.

Occurrence :

Found at localities R (Rongmuk Thainang) and T (Taikhimgithim)

Remarks :

This megalospheric form always occurs associated with A. regularia (Ghose) and shows all the characteristics of that microspheric form. Earlier Samanta (1961) described it as megalospheric companion of A. assamica Samanta which subsequently found to be synonymous with A. papillata regularia (Ghose) and so the name of the microspheric form has been changed to A. regularia (Ghose). But as Ghose did not report the megalospheric form the name A. subassamica is retained.

Assilina subassamica sijuensis Samanta, n. var.

(Pl. 5, figs. 13-18)

This is the megalospheric form of A. regularia sijuensis Samanta and shows all the characteristics of that variety. Test very small, flat with angular margin. Surface ornamentation similar to that of the microspheric companion. Internally the spire is regular. Outer whorls open rather rapidly in height. Chambers normally higher than long. Chamber walls straight and radial. Embryonic chambers bilocular; both the initial and the second chambers are rudely spherical in shape and nearly equal in size.

Measurements of *Assilina subassamica sijuensis*

Dimensions		Specimen shown on pl 5					
		Fig. 13	Fig. 14	Fig. 15	Fig. 16	Fig. 17	Fig. 18
Diameter ...	mm	4.6	5.1	4.3	3.9	5.3	4.8
Thickness ...	mm	0.85	0.9	—	—	0.9	0.8
Surface diameter of papillae	μ	400	300	—	—	—	—
Embryonic chambers:							
Diameters of initial chamber	μ	—	—	200×300	225×300	250×250	225×250
„ „ second chamber	μ	—	—	200×250	175×275	—	—
Distance across both chambers	μ	—	—	425	425	—	—
Whorls ...	number	—	—	4	4½	—	—
Chambers in first volution	number	—	—	6	6	—	—
„ „ final volution	number	—	—	23	22	—	—
„ „ all volutions	number	—	—	62	61	—	—

Occurrence:

Found at localities R (Rongmuk Thainang), D (Daranggiri) and S (Sonkiniggiri) in Garo Hills, Assam.

Assilina orientalis garoensis Samanta, v. var.

(Pl. 6, figs. 5-9)

Test small, lenticular with angular margin. Small raised granules are distributed throughout the surface.

Spire regular and the height of the whorls increases slowly and regularly. In general, chambers are slightly longer than high. Chamber walls are straight for nearly three fourths of their length and then recurve. The embryonic chambers are bilocular ; both the initial and the second chambers are circular in section and nearly equal in size.

The form is completely involute. Transverse sections show especially near the poles, numerous pillar structures continuous through succeeding laminae. Chambers as high as broad. Marginal cord thin.

Measurements of *Assilina orientalis garoensis*

Dimensions		Specimen shown pl. 6					
		Fig. 5	Fig. 6	Fig. 7	Not illustrated	Fig. 8	Fig. 9
Diameter ...	mm	4.1	3.8	4.7	4.5	3.1	4 1
Thickness ...	mm	2.0	1.6	—	—	1.4	1.6
Surface diameter of granules	μ	250	250	—	—	—	—
Embryonic chambers:							
Diameters of initial chamber	μ	—	—	200×225	250×275	160×225	225×300
Diameter of second chamber	μ	—	—	75×225	150×250	140×200	—
Distance across both chambers	μ	—	—	300	425	310	—
Whorls ...	number	—	—	5½	4½	—	—
Chambers in first volution	number	—	—	6	5	—	—
Chambers in final volution	number	—	—	22	19	—	—
Chambers in all volutions	number	—	—	77	60	—	-

Occurrence:

Found only at locality T (Taikhimgithim)

Remarks:

This variety differs from the typical A. orientalis in having mainly a more compressed test with uniformly granulated exterior. As in Indonesia, the microspheric companion does not occur also in Assam.

Assilina cf. umbilicata (Rutten)

(Pl. 6, figs. 10-14)

1915. Nummulites (Assilina) umbilicata Rutten, Jaarb. Mijnw. Ned. Ind. Verh II p. 61, figs. 32-36.

Test of medium size, compressed lenticular with central depression ; margin angular, sharp. Surface covered with very fine papillae which are larger and concentrated in the centrally depressed area ; away from the central depression the radial sutures appear as slightly raised lines of very close spaced small papillae.

Spire opens slowly and somewhat regularly. The chamber walls are oblique and gently curved. Chamber walls are thick and chambers are generally longer than high. Form semi-involute with numerous pillar structures, especially at the whorl junctions. Chambers in transverse section are nearly as high as broad. Marginal cord thin.

Measurements of *Assilina cf. umbilicata*

Dimensions		Specimen shown on Pl. 6					
		Fig. 10	Fig 11	Fig. 12	Fig. 13	Fig. 14	Not illustrated
Diameter ...	mm	10.7	11 2	10 5	9.6	9.4	9.0
Maximum thickness ...	mm	—	—	2.3	2.2	—	—
Thickness at centre ...	mm	—	—	1.9	1.7	—	—
Whorls ...	number	—	—	—	—	11	10
Chambers in first volution ...	number	—	—	—	—	7	6
Chambers in final volution ...	number	—	—	—	—	about 28	—

Occurrence :

Found only at locality R (Rongmuk Thainang) in Garo Hills, Assam.

Remarks :

The present form from Assam is comparable to A. umbilicata (Rutten) in the marked central depression of the test, semi-involuteness of the form and thick and curved chamber walls. It differs from Rutten's form in having the entire surface covered with fine papillae, rather inflated chambers in transverse sections and more curved septa. The present form belongs to the same group as A. exponens (Sowerby). But according to Rutten, A. umbilicata resembles closely A. spira (de Roissy) from Java (it is widely distributed and well known form A. spira corrugata de la Harpe). But original description and illustration of A. umbilicata do not suggest its relationship with A. spira group of forms. For proper information a restudy of the type material is required.

Assilina sp.

(Pl. 6, fig. 15)

This species is represented by one transverse section of microspheric form. The specimen is small, inflated, with marked polar depression and sloping peripheral part. Diameter 3.5 mm. Thickness at the inflated portion 1.3 mm. ; at the centre only 0.9 mm. There are about 6 whorls. Walls of the outer whorls do not reach the centre of the specimen. The height of the whorls increases slowly. Chambers are nearly as high as broad. Marginal cord thin. Pillar structures developed at the two inflated parts of the section.

Occurrence:

Locality R (Rongmuk Thainang) in Garo Hills, Assam.

Remarks:

This specimen resembles A. lacunata de Cizancourt in its small size, typical shape, thin marginal cord and shape of chambers in transverse section, But lack of sufficient material does not permit specific identification of this form.

REFERENCES

Archiac, E.J.A.D' and Haime, J., 1853: Description des animaux fossiles du Groupe Nummulitique de l'Inde. 373 pp., 36 pls. Paris.

Bemmelen, R.W. van, 1949: The Geology of Indonesia; Vol. IA-General geology of Indonesia and adjacent archipelagoes. The Hague, Netherlands Government Printing Office, 732 pp., ill.

Boussac, J, 1911: Etudes Paléontologiques sur le Nummulitique Alpin. Mém Carte géol. dét. Fr., Paris. vii+440 pp, atlas, 22 pls.

Carter, H.J., 1853: Description of some of the Larger Forms of Fossilized Foraminifera in Scinde; with observations on their internal structure. Ann Mag. Nat. Hist., London, Ser. 2, Vol. 11, pp. 161-177, pl.7.

———1861: Further Observations on the Structure of Foraminifera and on the Larger Fossilised Forms of Scinde, etc. including a new Genus and Species. Ann. Mag. Nat. Hist., London, Ser. 3, Vol. 8, pp. 309-333, 366-382, 446-465, pls. 15-17.

Caudri, C.M.B., 1934: Tertiary deposits of Soemba: Amsterdam, H.J. Paris, Publ. Pp. 1-223, Pls. 1-5.

Cizancourt, M. de and Cox, L.R., 1938: Contribution a l'études des Faunes Tertiaires de l'Afghanistan. Mém. Soc. Géol. Fr., Paris, N.S., Vol xvii, fasc. 1, no. 39, pp. 1-44, pls. 1-5.

Cole, W.S., 1958; Names of and variations in certain American larger Foraminifera, particularly the Camerinids-No.2. Bull. Amer. Pal., Vol.38, no.173, pp. 261-284, pls. 32-34.

———1960: The genus Camerina. Bull. Amer Pal, Vol.41, no. 190, pp. 189 193, pls. 23-26.

Davies, L.M., 1940: The Upper Kirthar beds of North-West India. Quart. Jour. Geol. Soc. London, Vol. 96, pt. 2, pp. 199-230, pls. 9-12, 1 table.

Doornink, H.W., 1932: Tertiary Nummulitidae from Java Geol mijnb. genootsch. Nederland. en Kolonien, Verh, Geol ser., Vol 9, pp. 267-315, 10 pls., 12 text-figs.

Douvillé, H., 1905: Le terrain Nummulitique du Bassin de l'Adour. Bull. Soc. Geol. France, Ser.4, Vol.5, pp. 9-55, 4 figs.

———1912: Les Foraminifera de l'île de Nias. Geol. Reichs-Mus. Leiden, Samml., Ser. 1, Vol. 8, pp. 253-278, pls. 19-21.

Eames, F. E., 1952: A contribution to the study of the Eocene in Western Pakistan and Western India: Discussion of the faunas of certain standard sections, and their bearing on the classification and correlation of the Eocene in Western Pakistan and Western India. Quart. Jour. Geol. Soc. London, Vol. 107, pt.2, pp. 173-196, 5 pls., 3 text-figs.

Ellis, B. F. and Messina, A.R, 1940-et seq: Catalogue of Foraminifera. New York. Amer. Mus. Nat, Hist., Spec. Publ., 30 Vols. and supplements, illus.

Furon, R., 1941: Geologie de l'Inde Orientale Francaise. France., Bur. Etudes Géol. et Miniéres Coloniales, Publ. no. 17, 26 pp., 2 pls, 4 text-figs, 1 table.

Gee, E.R., 1926: The Geology of the Andaman and Nicobar Islands with special reference to Middle Andaman Island. Rec. Geol. Sur. India, Vol. 59, pt.2. pp. 205-232, pls. 11-15.

Ghose, A.M.N., 1954: The Tura Sandstone Stage of the Garo Hills—its possible stratigraphic positions. Rec. Geol. Sur. India, Vol. 83, pt. 2, pp. 423-444.

Ghose, B.K., 1959: A preliminary note on the micropalaeontology of the Foraminiferal limestone from Theriaghat in Khasi Hills, Assam. Science and Culture, Vol.25, no.6, pp. 375-377, figs. 1-5.

Gill, W.D., 1953a: The Genus Assilina in the Laki Series (Lower Eocene) of the Kohat-Potwar basin, North-West Pakistan. Contr. Cush. Lab. Foram. Res., Vol.iv, pt 2, pp. 76-84, pls. 13 & 14, 2 text-figs.

———1953b: Facies and fauna in the Bhadrar beds of the Punjab Salt Range, Pakistan. Jour. Pal. Vol.27, no 6, pp.824-844,, pls. 88-91, text-figs 1-4, table.

Harpe, P. de la, 1879: Les Nummulites du Comté de Nice et échelle des Nummulites. Bull. Soc. Vaud. Sc. Nat., Vol. 16, no 82, pp. 201-243, pls.10.

———1926 : Materiaux pour servir a une monographie des Nummulites et des Assilines Rédigé par P. Rozlozsnik, A.M. Kir. Foldtani-Intezet-Evkonyve, Vol.27, pp.1-102, Budapest.

Heim, A. 1908 : Die Nummuliten und Flyschbildungen des Schweizer alpen Abhan. Sch. Pal. Gessel. Vol 35, pp 1-103, pls. 1-8.

Nagappa, Y., 1956 : Foraminifera of the genera Fabiana and Eornpertia from Sylhet limestone of Assam. Jour. Pal. Soc. India, Vol. I, no.1, pp 191-198.

———1959 : Foraminiferal Biostratigraphy of the Cretaceous-Eocene succession in the India-Pakistan Burma region. Micropaleontology, Vol. 5, no 2, pp.145-181, pls. 11, text-figs.11, charts 4, tables.

Nuttall, W.L.F., 1926 : The zonal distribution and description of the larger Foraminifera of the middle and lower Kirthar Series (Middle Eocene) of Western India. Rec. Geol. Sur. India, Vol.59, pp.115-164, pls. 1-8.

Rozlozsnik, P., 1927 : Einleitung in des studium der Nummuliten und Assilinen. Mitt. Jahrb. Unger Geol. Anst., Vol. 26, pp.1-154, pl.1, figs.

Rutten, L.M.R., 1915: In Waterschoot van der Gracht, W. van Bijdrage tot de geologie van Centraal Celebes. Jaarb, Mijnw. Ned. 1914, verh. II, 16-74 Batavia

Sale, H.N. & Evans, P, 1940 : The Geology of British Oil-fields. 1. The Geology of the Assam-Arakan Oil Region (India and Burma). Geol. Mag. Vol. LXXVII, No. 5, pp. 337-463.

Samanta, B K., 1961 : New species of Assilina d'Orbigny from Kirthar rocks of Garo Hills, Assam. Quart. Jour. Geol. Min. Met. Soc. India, Vol.33, no.2, pp. 89-90, figs. 1-8.

———1962 : Assilina from the Eocene rocks of Garo Hills, Assam (Abstract). Indian Sc. Cong. 49th Proc., pt. 3, p.199.

Schaub, H , 1961 : Uber die Genusnamen der Nummulitidae : Nummulites, Assilina und Operculina. Eclog. Geol. Helv., vol 54, pp.566-569.

Sowerby, J. de C., 1840 : Systematic description of organic remains from Cutch. Trans. Geol. Soc. London Ser.2, Vol.5, pp.327-329, pls. 21-26.

Tipper, G.H., 1911 : The Geology of the Andaman Islands, with reference to the Nicobars. Mem. Geol. Sur. India, Vol.35. pt.4.

Verbeek, R.D.M. and Fennema, E.R., 1896: Description geologiqne de- Java et Madoura, Amasterdam, 2v.

Vredenburg, E.W., 1906a : Nummulites douvillei, an undescribed species from Kachh with remarks on the zonal distribution of Indian Nummulites. Rec. Geol. Sur. India, Vol.34, pt.2, pp. 79-95.

———1906b : The classification of the Tertiary system in Sind with reference to zonal distribution of the Eocene Echinoidea described by Duncan and Sladen. Rec. Geol. Sur. India, Vol. 34, pt. 3, pp.172-198.

West, W.D., 1949; General report for the year 1939. Rec. Geol. Sur. India, Vol.78, pt.1., p.20.

Wilson, G.F. and Metre, W.B., 1953 : Assam and Arakan. in Illing, V.C., (ed.) The world's oilfields : The Eastern Hemisphere (The Science of Petroleum, Vol.6, pt.1), London. Oxford University Press, pp.119-123.

Ziegler, J.H., 1960 : Die Assilinen des Eozans vom Kressenberg in Oberbayern. Geol. Bavarica, no.44, pp. 209-231, pls. 1-4, 2 diagrams.

EXPLANATION OF PLATES

Plate 1

Figs. 1-4, 6-9, 11-15. *Assilina spira corrugata* de la Harpe.
1-4, 6. External views; 1, ×1.5; 2, ×1.2; 3, ×1.6; 4, ×1.2; 6, ×1.6.
7-9. Equatorial sections; 7, ×2.5; 8, ×2.3; 9, ×2.3.
11-15. Transverse sections; 11, ×3.8; 12, ×3.3; 13, ×3.3 (section of fig.4); 14, ×4; 15, ×3.3, from the same sample as fig.6.

Figs. 5, 10, 16. *Assilina spira taikhimensis* Samanta, n. var.
5. External view; holotype, ×2.2.
10. Equatorial section, ×3.2.
16. Transverse section, ×3.6.
4, 6, 15 from Loc. R (Rongmuk Thainang); rest from Loc. T (Taikhimgithim),

Plate 2

Figs 1-6, 9-11, 14-17. *Assilina subspira corrugata* Samanta, n. var.
1-6. External views; 1, ×2.3; 2, ×2 3; 3 (holotype), ×2.1; 4, ×2.1; 5, ×2.1; 6, ×2 1.
9-11. Equatorial sections; 9, ×5.8; 10, ×4.5; 11, ×4.5.
14-17. Transverse sections; 14, ×10; 15, ×10; 16, ×10; 17, ×6;

Figs. 7, 8, 12, 13 & 18 *Assilina subspira rongmukensis* Samanta, n. var.
7, 8. External views; 7, ×1.5; 8 (holotype), ×6.1
12, 13. Equatorial sections; 12, ×6.1; 13, ×7.1.
18. Transverse section, ×12.1.

Figs. 19-21. *Assilina subsimsongi* Samanta, n. sp.
19. External view, ×8.
20. Equatorial section, ×7.5.
21. Transverse section, ×11.5.
7, 8, 12, 13, 18 from Loc. R (Rongmuk Thainang); rest from Loc. T (Taikhimgithim).

Plate 3

Figs. 1-11. *Assilina simsongi* Samanta, n. sp.
1-4. External views; 1, ×2; 2, ×2; 3, ×3.5; 4 (holotype), 4 5.
5-7. Equatorial sections; 5, ×4.8; 6, ×4.5; 7, ×4.5;
8-11. Transverse sections; 8, ×7.8; 9, ×9; 10, ×6.8; 11, ×6.

Figs. 12-15. *Assilina subsimsongi* Samanta, n. sp.
12-13. External views; 12, ×5; 13 (holotype), ×5.
14. Equatorial sections, ×7.
15. Transverse sections, ×18.
All the specimens from Loc. T (Taikhimgithim).

Plate 4

Figs. 1-13. *Assilina regularia* (Ghose).
1-6. External views; 1, ×2.4; 2, ×1.6; 3, ×2.2; 4, ×1.6; 5, ×1.6; 6, ×2.2
7-9. Equatorial sections; 7, ×2.5; 8, ×3; 9, ×2.6.
10-13. Transverse sections; 10, ×5.2; 11, ×5.0; 12, ×7.2; 13, ×7.

Figs. 14-16. *Assilina subassamica* Samanta.
Equatorial sections; 14, ×6.5; 15, ×5.5; 16, ×4.2.
All specimens from Loc. R (Rongmuk Thainang).

Plate 5

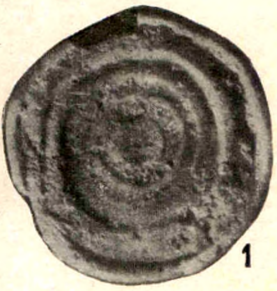
Figs. 1-12.	*Assilina regularia sijuensis* Samanta, n. var.
	1-5. External views ; 1, (holotype), ×2 ; 2, ×2 ; 3, ×2.2 ; 4, ×2 ; 5, ×2.
	6-8. Equatorial sections ; 6, ×3 ; 7, ×3.5 ; 8, ×4.5.
	9-12. Transverse sections ; 9, ×5.8 ; 10, ×5.8 ; 11, ×4 ; 12, ×7.
Figs. 13-18.	*Assilina subassamica sijuensis* Samanta, n var.
	13-14. External views ; 13, ×8.5 ; 14, (holotype), ×8.
	15-16. Equatorial sections ; 15, ×8 ; 16, ×8.5.
	17-18 Transverse sections ; 17, ×4 ; 18, ×8.5.
Figs. 19-21.	*Assilina subassamica* Samanta.
	Transverse sections ; 19, ×14.2 ; 20, ×15.4 ; 21, ×10.8.
	All specimens from Loc. R. (Rongmuk Thainang).

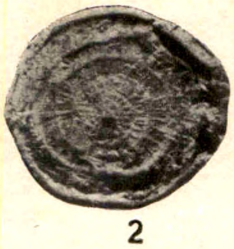
Plate 6

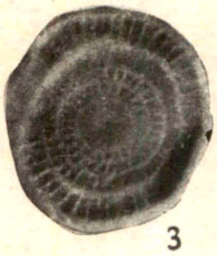
Figs. 1-4.	*Assilina subassamica* Samanta.
	External views ; 1, ×2.8 ; 2, ×4.4 ; 3, ×3.8 ; 4, ×2 8.
Figs. 5-9.	*Assilina orientalis garoensis* Samanta, n. var.
	5-6. External views ; 5, (holotype), ×7.5 ; 6, ×7.5.
	7. Equatorial section , ×8.
	8-9. Transverse sections ; 8, ×15 ; 9, ×8.
Figs. 10-14.	*Assilina cf. umbilicata* (Rutten).
	10-11. External views ; 10, ×2 ; 11, ×2.
	12-13. Transverse sections ; 12, ×6.7 ; 13, ×6.7.
	14. Equatorial section, ×5.
Fig. 15.	*Assilina sp.*
	Transverse section, ×8.2.
	5-9, from Loc. T (Taikhimgithim) ; rest from Loc. R. (Rongmuk Thainang)

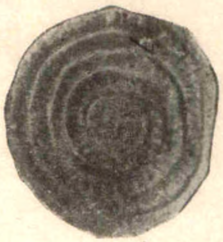
ERRATA

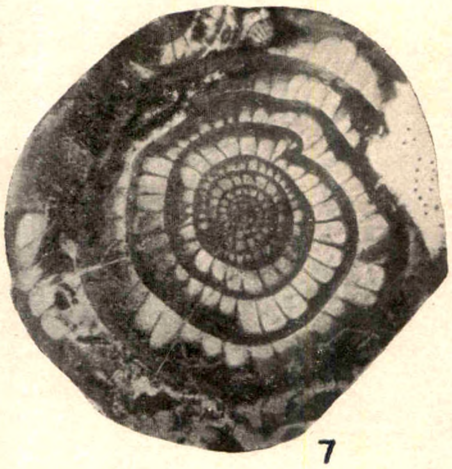
Page	Line	Incorrect	Correct
1	13	sp. A.	sp. A
3	17	subancellata	subcancellata
3	31	(1459)	(1954)
7	5	sp. A.	sp. A
7	8	A.	A
8	5	Monographic	Monographie
11	3		Fig. 17 in last column
11	4	8.6 below Fig. 16	6.7 below Fig. 16
11	7	350 ×	350 × 550
11	8	190 × 35	190 × 350
12	5	curnvature	curvature
23	25	Sale, H.N.	Sale, H.M.

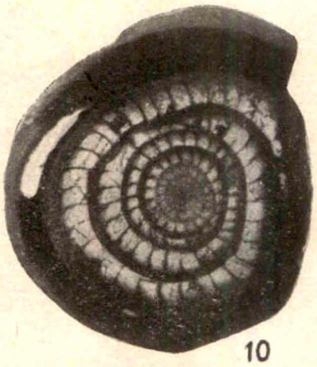

1

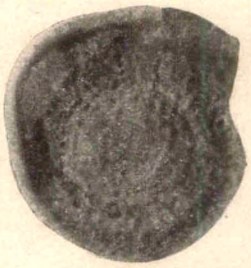

2

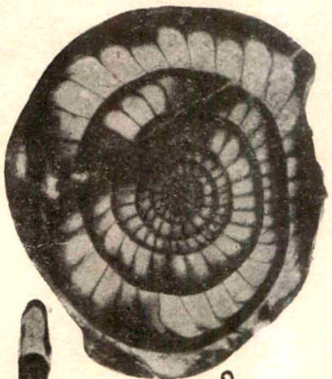

3

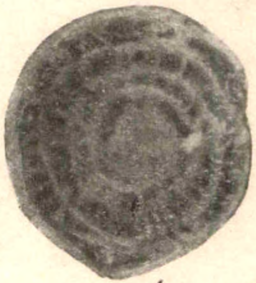

4

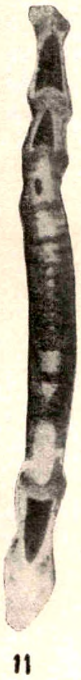

7

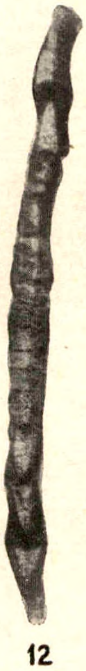

10

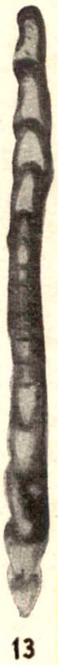

5


8


6


11

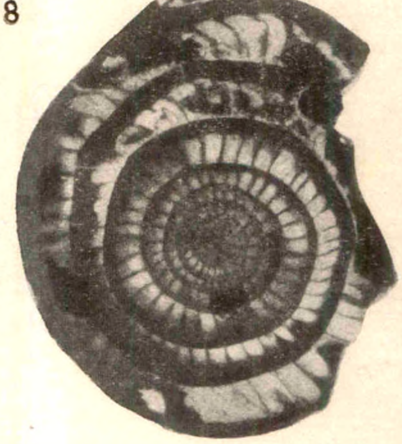

12

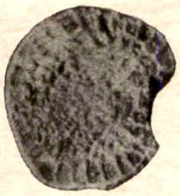

13

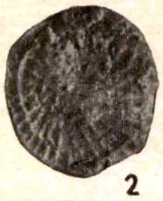
14

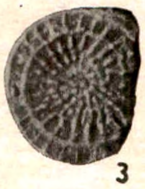
15

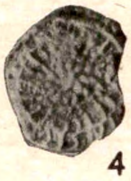
16

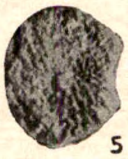

9

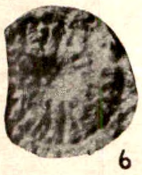

1

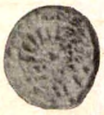

2

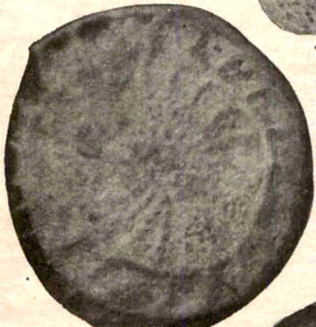

3

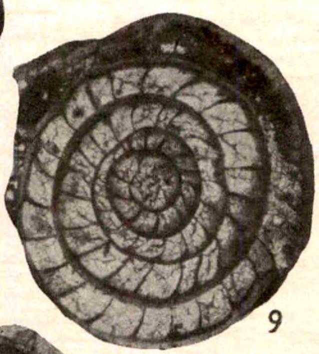

4

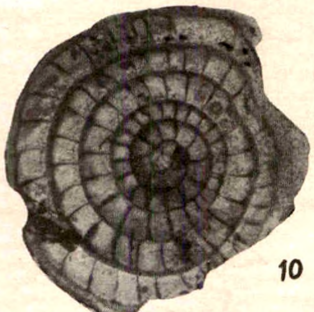

5

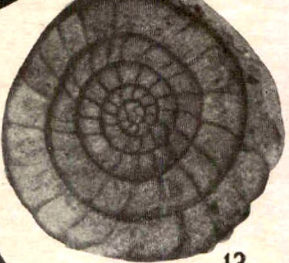

6

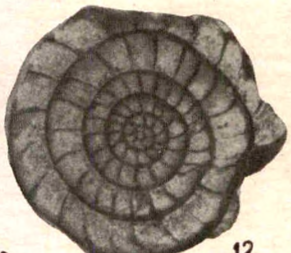

7

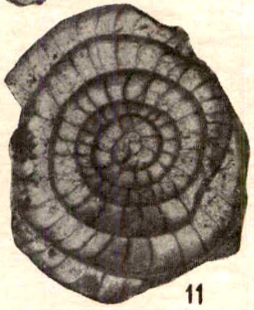

8

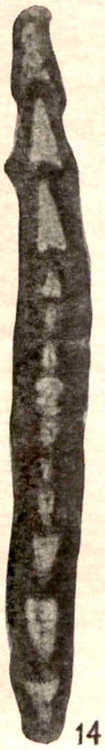

9


10

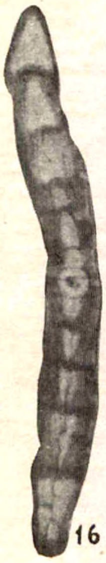

13

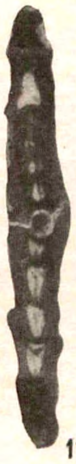

12

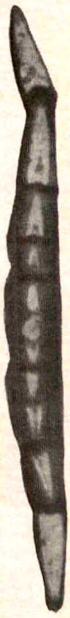

11

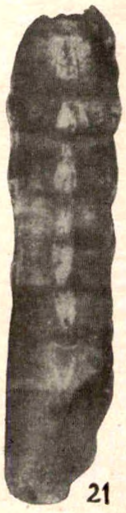

14

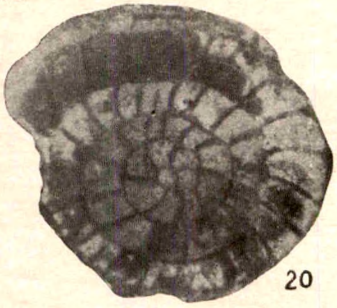
15

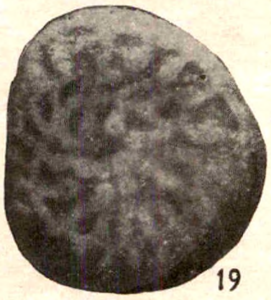

16

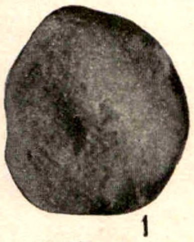

17

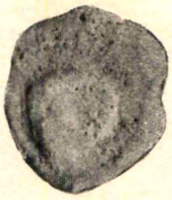

18

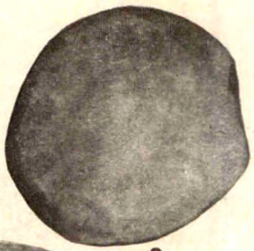

21

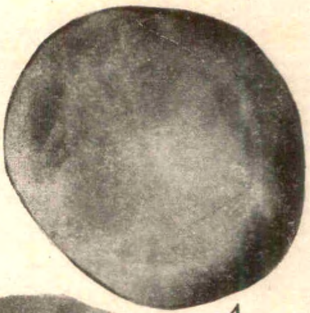

20

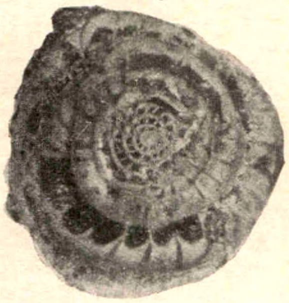

19

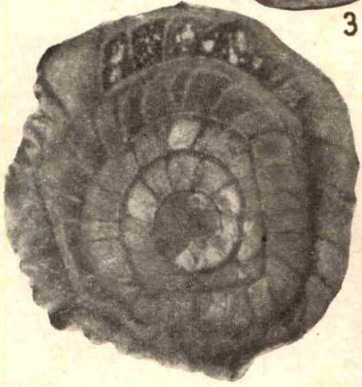

1

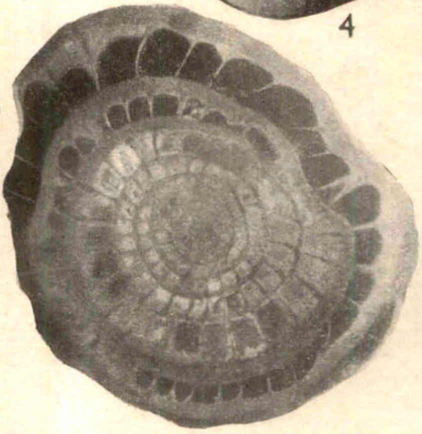

2

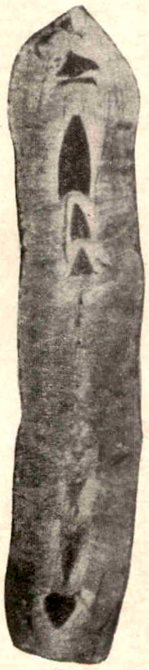

3

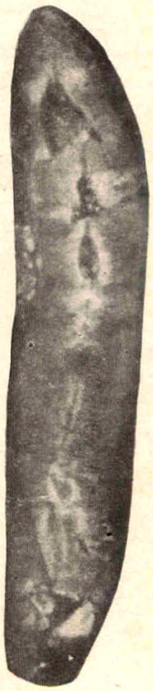

4

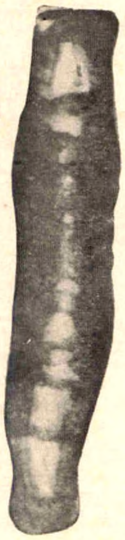

5

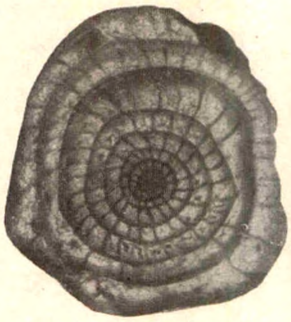

14

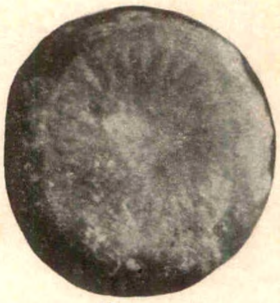

6

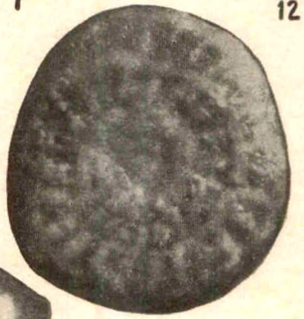

8

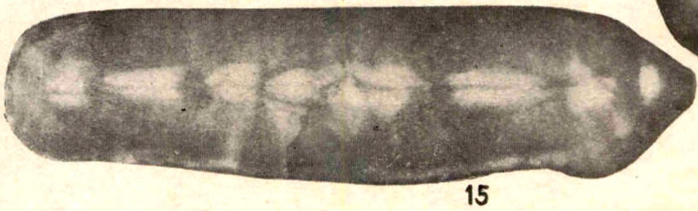

9

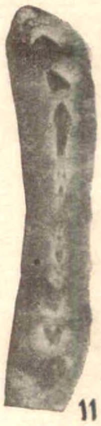

10

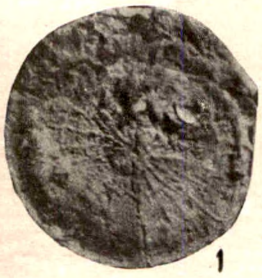

7

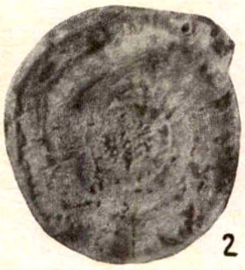

12

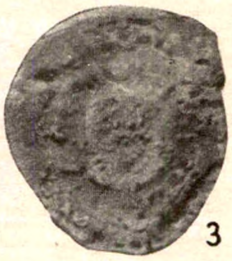

13

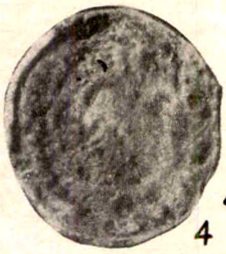

15

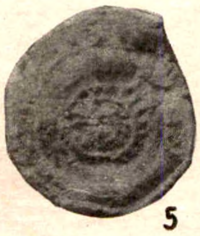

11

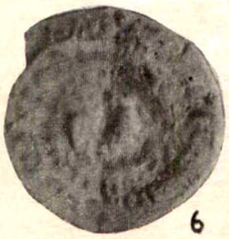

1

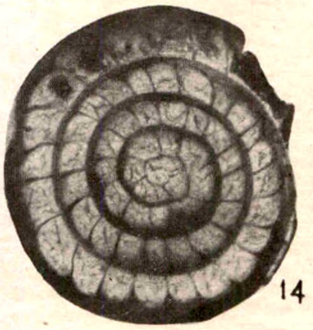

2

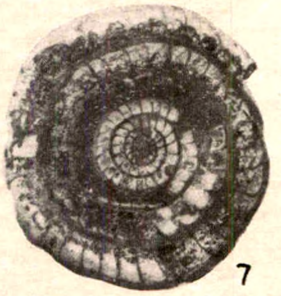

3

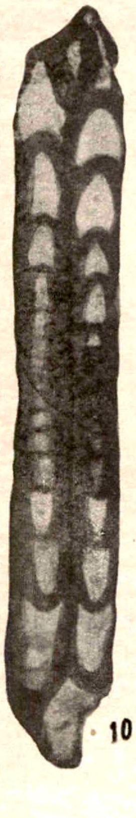

4

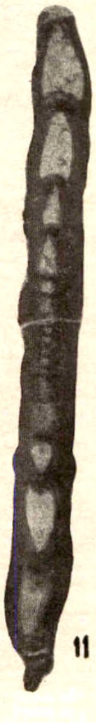

5

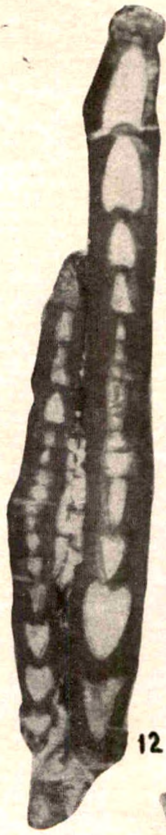

6

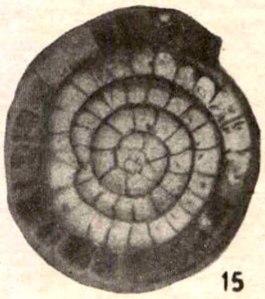

14

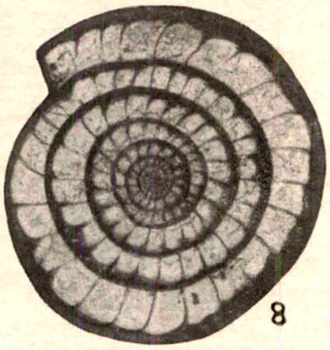

7

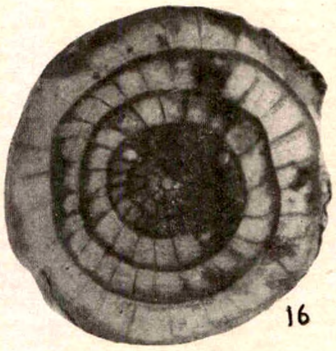

10

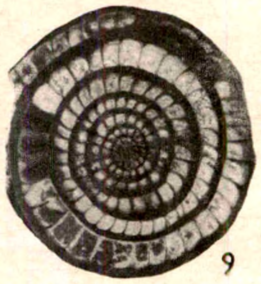

11

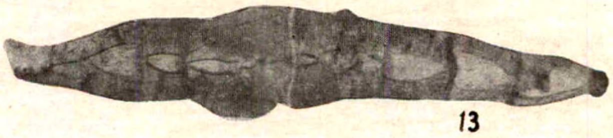

12

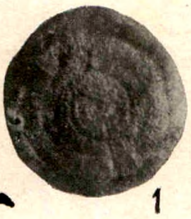

15

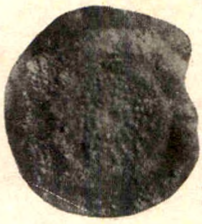

8

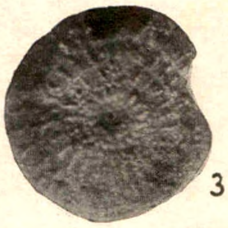

16

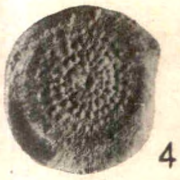

9

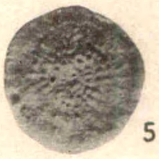

13

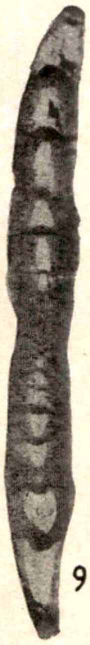

1

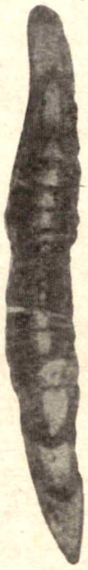

2

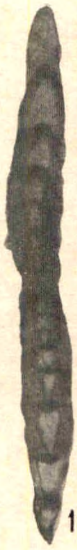

3

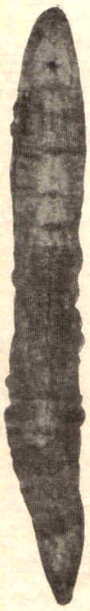

4

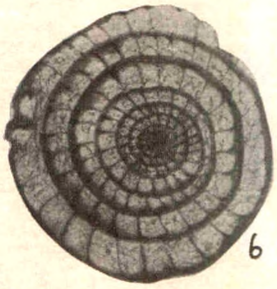

5

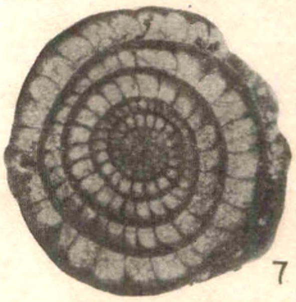

9

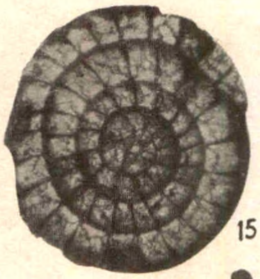

10

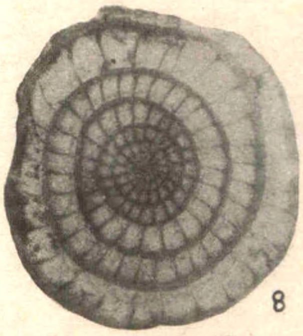

11

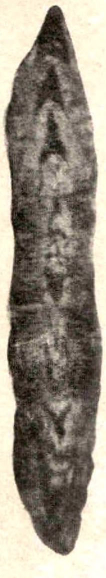

12

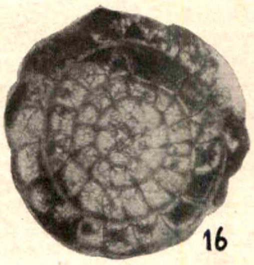

6


7

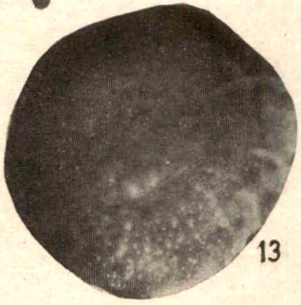

15

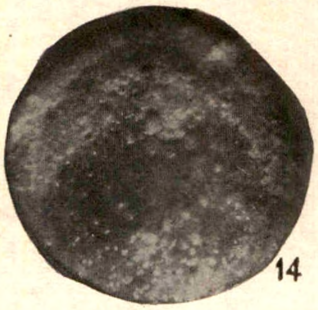

8

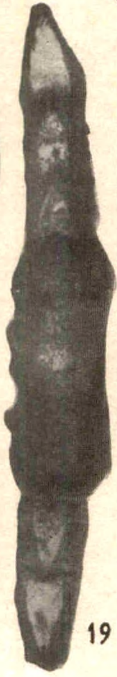

17

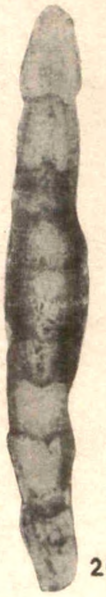

16

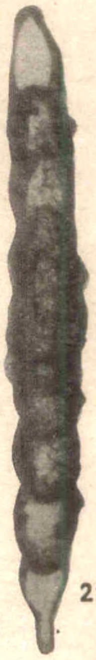
18


13

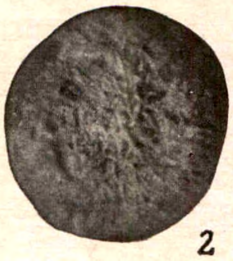

14

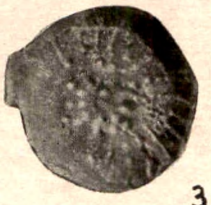

19

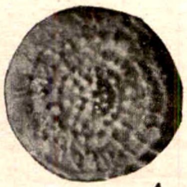

20

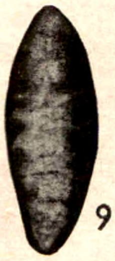

21

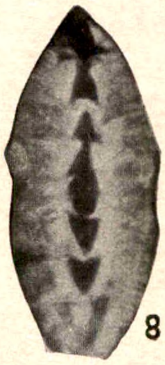
1

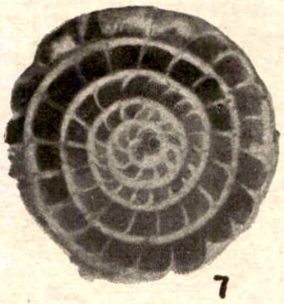

2

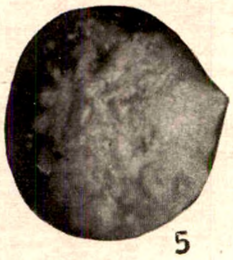

3

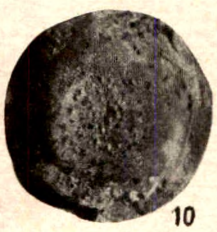

4

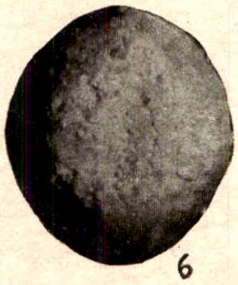

9

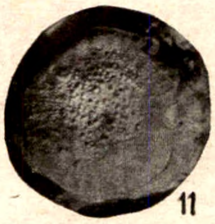

8

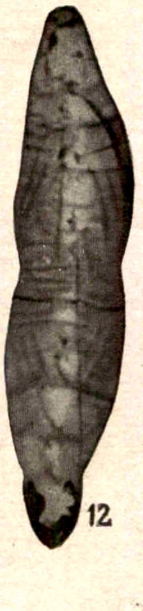

7

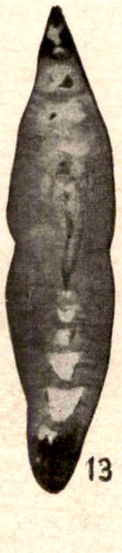

5

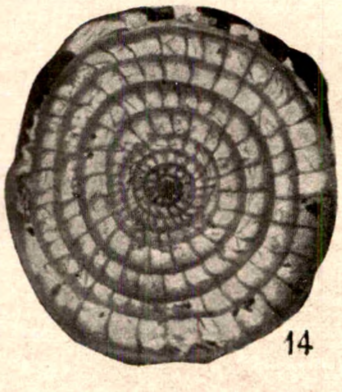

10

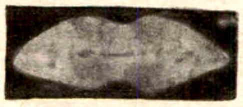

6


11


12


13


14


15

BULLETIN
OF THE
Geological, Mining & Metallurgical
Society of India

NO. 28 JANUARY, 1963

CALCUTTA UNIVERSITY
CENTRAL LIBRARY

Upper Cretaceous smaller foraminifera from the Gypseous Clays of the 'Uttattur Beds' of the Uttattur* Group, Trichinopoly District, Madras State.**

(With Plate I and Fig. 1)

By

RUPENDRA MOHAN DAS & BHASKAR PRASAD CHATTERJEE

ABSTRACT:

Fortyseven species of smaller foraminifera inclusive of two sub-species are described from the gypseous clays of the Uttattur beds. Seventeen of them are not definitely determined for the time being. Twentyfive species, however, appear to be similar to the Upper Cretaceous Austin-Taylor and Navarro stages of North America. Two of these sub-species, *Globotruncana rosetta rosetta* Carsey and *G. ventricosa ventricosa.* White are reported from the Colon Shale Formation of Columbia, South America. Species like *Globigerina cretacea* d'Orbigny, *Lagena* cf. *globosa* Montagu, *Ramulina globulifera* Brady and *Gyroidina beisseli* White are previously recorded from the Upper Cretaceous of North-West basin of Western Australia and New Mexico. Thus it appears that these species of foraminifera of the Uttattur beds are similar to the species of Senonian age ranging from Coniacian to Maestrichtian. The species are, however, compared (types being unavailable) with the illustrations.

Ootatoor (Uttattur) Beds of Uttattur Group:

Author: Blanford, H. F., p. 23, 1862.

Type area: The group owes its name to the Uttattur village (11.4/78.51) in the District of Trichinopoly, Madras State, where it is developed. The group is made up of two rock-units. A coral-reef limestone is at the base. This basal unit occurs as detached outcrops toward the western border of the group. A more widespread, shale-siltstone-gypseous clay unit intercalated with concretions and nodules of ferruginous, calcareous and phosphatic material occurs at the top. This upper unit is designated as the Uttattur beds of Blanford. Exact relation between these two constituent rock-units of the Uttattur group was neither clear to Blanford, (p. 56) in 1862, nor it could be established by the present authors.

---

* Spelling used in this paper are after the present Survey of India toposheet No. 58(I/16) (Scale 1 inch to mile).

** Read before the Society on 4. 1. 63.

Type section: No measured type-section of the Uttattur Group is available.

Typical sections: Typical sections are known to occur at a number of localities from Blanford's own record. In all instances the measured sections are unavailable.

Lithology: The Uttatur beds present much variety—fine silt, calcareous and argillaceous shales, sandy and gypseous clays, frequently tinted with ochreous matter. They also contain angular fragments of shale from the plant beds (Uttattur plant beds occurring at the base of the marine Uttattur group) and concretions and nodules of ferruginous, calcareous and phosphatic material. Occasionally they are unconsolidated. South of Karai (11.8/78.53) and Garudamangalam (11.5/78.55) the Uttattur beds consist almost exclusively of laminated sands, clays and argillaceous shales with comparatively few fossils.

Lower contact: The Uttattur group rests undisturbed either upon the gneiss (crystalline complex) or upon the Uttattur plant beds. The Uttattur beds which is dealt with as uppermost beds of the Uttattur group behave likewise: they are seen to cap (in addition to the gneiss and the plant beds) the detached outcrops of coral reef limestone toward north-side of the basin.

Upper contact: The Uttattur beds are unconformable to the Upper Cretaceous Trichinopoly Group.

Structure: Least known. Hypothetical statements are various—but without a number of digs into the basin itself, precise information will not be available.

Thickness and areal distribution of the Uttattur beds: The Uttattur beds occupy a strip of country about thirty miles in length and three to four miles in average width. It appears to be widest between Uttattur (11.4/78.51) and Maruvattur (11.12/78.57). These beds contract rapidly to the north and south both along its length and breadth.

Incidentally it may be pointed out in passing that the present work is also confined between Maruvattur to the north and Uttattur to the south. Samples of gypseous clays are drawn by the authors from within a depth of 6 ft. from the surface at the following localities (in a north-south direction): Maruvattur (11.12/78.57), Kalpadi (11.11.30/78.55.30), Panangur (about 1.5 miles south-south-west of Maruvattur), Varagupaddy (11.9.30/78.54), Kudikkadu (about 3 miles north-east of Karai), Sirukanbur (about 3.2 miles north-east of Karai), Nattakkudu (about 4.9 miles east-north-east of Karai), Karai

(11.8/78.53), Kulakkalnattam (about 5 miles east of Karai), Ayinapuram (about 3.5 miles east-south-east of Karai), Ukkalur (about 1.8 miles north-east of Uttattur), Uttattur (11.4/78.51), Nallur (about 3 miles north-east of Uttattur), Nambakkurichchi (about 1.2 miles south-east of Uttattur), Terkumadevi (about 4.2 miles north-east of Karai).

These beds are variable in composition and thickness both along its length and breadth. Gypseous clays predominate over the rest of components. No quantitative estimate of either of the composition or of the thickness of this unit is possible without adequate bore-hole data. Speaking qualitatively they appear to be more sandy toward the north and clayey toward the south. Pelagic ammonites and bottom-dwelling other molluscs are frequent to the north, whereas they are practically absent to the south.

Blanford estimated thicknesses of the Uttattur beds from three localities as 720 ft., 1900 ft. and 400 ft. within a distance of 7 and 8 miles respectively from one another and this calculated thickness was based primarily on the assumption that the beds are horizontal throughout and their dip is even and does not exceed eight degrees.

The bedding is however irregular (p. 89) and they were laid down on an irregular sea floor.

Fossils, Age and Palaeoecology: North of Karai (11.8/78.53) the Uttatur beds are characterised by pelagic cephalopods and bottom-dwelling molluscs and annelids. South of Karai these are practically absent except for probably a few drifted genera from the north. The geological age of the Uttattur beds was derived chiefly from the fossil cephalopods and molluscs occurring in them.

In Blanford's opinion the fossil cephalopods bore greatest resemblance with the fauna of the Gault, Upper Greensand and even Neocomian of Western Europe.

Dr. Stoliczka (1861-1873) was more directly concerned with the systematic descriptions of the fossil collections from the Cretaceous deposits of various parts in South India than with the specific determination of the geological age of the Uttattur beds.

In later years Dr. Kossmat subdivided the Uttattur beds into a three-fold unit—lower, middle and upper on the basis of the ammonites and other molluscs occurring in the Uttattur beds. These fossil shells, in his opinion, were similar to those animals occurring in the Upper Albian, Cenomanian and lower Turonian beds of Europe. A three-fold subdivision of the Uttattur beds and the consequent geological age of the beds has been maintained almost as an article of faith in our geology. It does not appear to have been checked up in field practice, and the boundary surfaces between the different layers remain obscure.

Prof H. C. Dasgupta (1922) reported on some smaller foraminifera (Globigerina sp., Nodosaria sp., Textularia sp.) from the phosphatic nodules of the Uttattur beds.

Drs. K. Jacob and M. V. A. Sastri (1951) reported on the occurrence of *Globotruncana appennica* (Renz), *Globo. indica* sp. nov., and ascribed a Cenomanian age to the Uttattur beds.

Messrs. M. V. A. Sastri and V. V. Sastri (1962) (Micropalaeontology, no. 2, p. 276) have reported on their finding of 25 genera and 30 species of smaller foraminifera of Upper Albian age from the Uttattur beds.

The authors regret having overlooked giving synonymy in their proper places.

Stratigraphic status: Smaller foraminifera (from the Gypseous clays of the localities given on a previous page) described by the authors in this paper indicate tentatively that they are of Senonian age. This is an ugly revealation and it contradicts our conceptions of the geological age of the Uttattur beds.

On the other hand the record of the Upper Cretaceous foraminifera in this report brings the authors nearer to the hypothesis of the Upper Cretaceous embayment of Blanford (p. 103-105) and the manner of sedimentation during the Uttattur period.

The foraminifera described here are obtained from random samples collected from only a few localities of the Uttattur beds. The result of our studies indicates that the relative stratigraphic positions, of the different layers of the gypseous clays were not definitely known at the time of collection.

It appears to the authors that the Gypseous clays of the Uttattur group which constituted the main bulk of the Uttattur beds of Blanford range up to Senonian of the Upper Cretaceous.

Acknowledgement:

This work was carried out in partial fulfilment of the M.Sc. Examination in Geology of the Calcutta University under the supervision of A. Chaudhuri. Grateful acknowledgement is accorded to Prof. N. N. Chatterjee, Head of the Department of Geology, Calcutta University for rendering partial financial assistance for field work. Our thanks are also due to Manager, Trichinopoly Mining Works, Muthuveerama Reddiar, B. N. Das and N. C. Das for helping us in various ways. To Mr. B. Biswas the authors are thankful for specific information on the Austin-Taylor and Navarro stages. To Asoke Banerjee, a fellow student at Ashutosh College and now with the World Press Private Ltd., they are deeply indebted for pushing through the publication of the paper.

THE FIGURED SPECIMENS ARE DEPOSITED IN THE GEOLOGICAL LABORATORY, CALCUTTA UNIVERSITY

SYSTEMATIC DESCRIPTION OF THE FORAMINIFERA

Family—**LAGENIDAE**

Sub-Family—**Nodosariinae**

Genus—**ROBULUS Montfort, 1808**

Robulus munsteri (Romer) Cushman
[U.S.G.S. Prof. paper, 206, Pl. 17, fig. 8]
(Pl. 1, Fig. 1)
Specimen No. 4/26 N (12)

Description: Test planispiral, involute; periphery keeled; last volution with 7 distinct chambers; sutures limbate, curved; umbilicus with a boss; wall smooth, perforate; aperture radiate, at the peripheral angle.

Locality: Sirukanbur ridge (25), Nattakkudu ridge (26), Terkumadevi ridge (27), Ukkalur ridge (17) and Nambakkurichi ridge (20).

Remarks: This sp. has got resemblance with R. munsteri of Gulf Coast of Navarro, Taylor & Austin age.

Robulus pondi Cushman
[U.S.G.S. Prof. paper 206, Pl. 16, fig. 1 (a), (b)]
(Pl. 1, Fig. 4)
Specimen No. 4/27 M (10)

Description: Test planispiral, involute; peripheral margin subangular; last volution with 8 chambers, sutures curved; umbilicus with a boss; wall smooth, perforate; aperture peripheral, terminal and rounded.

Locality: Kulakkalnattam ridge (28), Nattakkudu ridge (26), Terkumadevi ridge (27) and Nallur ridge (30).

Remarks: This form has remarkable similarity with Gulf Coast form R. pondi of Navarro and Taylor age.

Robulus pseudo-secans Cushman
[U.S.G.S. Prof. paper 206, Pl. 17, fig. 12]
(Pl. 1, Fig. 2)
Specimen No. 4/27 M (18)

Description: Test planispiral, involute, gradually thinning from the umbo to the periphery which is acute and keeled, last volution with 9 distinct chambers; sutures greatly limbate and raised; umbilicus with a boss; wall smooth, perforate; aperture at the peripheral angle, rounded.

Locality: Kudikkadu ridge (12), Terkumadevi ridge (27).

Remarks: This form has a similarity with R. pseudo-secans described from Gulf Coast Up. Cretaceous of Navarro and Austin age.

Robulus stephensoni Cushman
[U.S.G.S. Prof. paper 206, Pl. 18, fig. 13 (a, b)]
(PL. 1, FIG. 3)
SPECIMEN NO. 5/28 SW (32)

Description: Test planispiral, involute, periphery with a narrow keel, last whorl with 10 chambers; sutures curved, limbate; umbilicus narrow; wall smooth, perforate; aperture at the peripheral angle, rounded.

Locality: Varaguppadi ridge (10), Kulakkalnattam ridge (28).

Remarks: This form has remarkable similarity with Gulf Coast form R. stephensoni of Navarro and Taylor age.

Genus—**FRONDICULARIA Defrance, 1824**

Frondicularia arkadelphiana Cushman
[U.S.G.S. Prof. paper 206, Pl. 37, fig. 21]
(PL. 1, FIG. 7)
SPECIMEN NO. 4/26 N (1)

Description: Test elongate, narrow, compressed, with inverted 'V' shaped chambers; initial end with a spine; wall perforate, surface with fine parallel, longitudinal costae; aperture terminal, at the end of the last chamber.

Locality: Nattakkudu ridge (26).

Remarks: This form has resemblance with F. arkadelphiana described from the Up. Cret. (Navarro age) of Gulf Coast.

Frondicularia archiaciana d' Orbigny
[U.S.G.S. Prof. paper 206, Pl. 37, fig. 20]
(PL. 1, FIG. 15)
SPECIMEN NO. 1/20 N (4)

Description: Test elongate, gently tapering, greatest breadth toward the apertural end, compressed, sides flattened; five chambers distinct, inverted V-shaped, not inflated; sutures distinct, limbate; surface smooth, wall perforate; aperture terminal; periphery truncated.

Locality: It has been recorded from Nambakkurichi ridge (20).

Remarks: Rare, It strongly resembles F. archiaciana which has been described from the U.S. Gulf Coast of Navarro and Taylor age.

Frondicularia goldfussi Reuss
[U.S.G.S. Prof. paper 206, Pl. 35, fig. 1]
(PL. 1, FIG. 16)
SPECIMEN NO. 29/6 E (6)

Description: Test elongate, thin, compressed with a basal spine; chambers chevron shaped, increasing very slightly in width as added, four chambers distinct; sutures distinct, progressively more curved; slightly limbate, not rising above the smooth, flattened ; periphery distinctly truncate ; surface smooth ; wall perforate.

Locality: It has been found from Ayinapuram ridge (6), Nambakkurichi ridge (20), Sirukanbur ridge (25), Kulakkalanattam ridge (28), Terkumadevi ridge (27).

Remarks: Rare. It is nearly identical with the species that has been described from Taylor and Austin age of U.S. Gulf Coast.

Genus— **DENTALINA d'Orbigny, 1826**

Dentalina gracilis d'Orbigny

[U.S.G.S. Prof. paper 206, Pl. 23, fig. 4]

(PL. 1, FIG. 6)

SPECIMEN NO. 30/10 SSE (3)

Description: Test elongate, slightly curved ; 8 chambers, chambers more or less gradually increasing in size ; sutures oblique ; wall smooth, perforate ; aperture terminal, radiate.

Locality: Varaguppadi ridge (10), Sirukanbur ridge (25) and Ayinapuram ridge (6).

Remarks: This form has resemblance with D. gracilis described from the Up. Cret. (Navarro, Taylor and Austin age) of Gulf Coast.

Genus—**NODOSARIA Lamarck, 1812**

Nodosaria affinis Reuss

[U.S.G.S. Prof. paper 206, Pl. 25, fig. 11]

(PL. 1, FIG. 11)

SPECIMEN NO. 30/10 SSE (6)

Description: Test uniserial, straight, with 5 chambers ; sutures transverse; wall perforate, surface with numerous parallel, longitudinal costae ; aperture terminal, radiate.

Locality: Varaguppadi ridge (10), Nattakkudu ridge (26), and Karai ridge (4).

Remarks: This form has similarity with Nodosaria affinis of Gulf Coast Up. Cret. (Navarro, Taylor and Austin age).

Genus—**MARGINULINA d'Orbigny, 1826.**

Marginulina jarvisi Cushman

[U.S.G.S. Prof. paper 206, Pl. 22, fig. 18(a, b)]

(PL. 1, FIG. 5)

SPECIMEN NO. 30/10 SSE (2)

Description: Test elongate, subcylindrical, earliest portion close coiled, later uncoiled, becoming straight ; 9 chambers distinctly seen ; sutures oblique ; wall smooth, perforate ; aperture terminal.

Locality: Varaguppadi ridge (10), Kulakkalnattam ridge (28), Sirukanbur ridge (25), Ukkalur ridge (17) & Nambakkurichi ridge (20).

Remarks: This form has remarkable similarity with M. jarvisi of the Up. Cret. (Navarro age) of Gulf Coast.

Marginulina navarroana Cushman

[U.S.G.S. Prof. paper 206, Pl. 22, fig. 5]
(Pl. 1, Fig. 4)
Specimen No. 30/12 NNW (24)

Description: Test elongate, early portion close coiled, later uncoiled with 4 distinct chambers ; sutures slightly curved ; wall perforate ; surface with parallel, longitudinal costae ; aperture terminal, at the end of a small neck.

Locality: Kudikkadu ridge (12).

Remarks: This form has resemblance with M. navarroana of Gulf Coast Up. Cret. (Navarro age).

Marginulina texasensis Cushman

[U.S.G.S. Prof. paper 206, Pl. 21, fig. 26]
(Pl. 1, Fig. 45)
Specimen No. 1/19 W (9)

Description: Test elongate, slender, early portion coiled, becoming uncoiled ; ventral margin convex, lobulated ; dorsal margin slightly concave ; six chambers distinct, inflated, increasing gradually in height towards the apertural end ; sutures distinct depressed, especially in the later portion ; surface smooth, wall perforate ; aperture radiate, at the peripheral angle.

Locality: It has been recorded from Uttattur ridge (19).

Remarks: It resembles closely with M. texasensis Cushman which has been described from Navarro and Taylor age of U.S. Gulf Coast.

Marginulina curvatura Cushman

[U.S.G.S. Prof. paper 206, Pl. 22, fig. 12]
(Pl. 1, Fig. 38)
Specimen No. 1/20 N (16)

Description: Test elongate, early portion coiled and later with uncoiled chambers ; five chambers distinct, unequal, becoming gradually inflated more toward the apertural end ; sutures distinct, oblique, depressed, surface smooth, wall perforate ; aperture at the peripheral angle, circular.

Locality: It has been found from Nambakkurichi ridge (20), Kudikkadu ridge (12) and Kulakkalnattam ridge (28).

Remarks: Rare. Agrees strongly with M. curvatura which has been described from Navarro age of U.S. Gulf Coast.

Genus—**SARACENARIA Defrance, 1824**

Saracenaria triangularis (d'Orbigny) Cushman & Church

[U.S.G.S. Prof. paper 206, Pl. 28, fig. 3]
(Pl. 1, Fig. 9)
Specimen No. 30/12 NNW (26)

Description: Test elongate, triangular, early portion slightly coiled, later uncoiled, becoming straight ; 8 distinct chambers seen gradually increasing in size; sutures distinct, curved; wall smooth, perforate; aperture terminal, at the peripheral angle which is sharp.

Locality: Kuddikkadu ridge (12) and Karai ridge (4).

Remarks: This sp. has remarkable similarity with S. triangularis described from Up. Cret. (Navarro, Taylor & Austin age) of Gulf Coast, U.S.A.

Saracenaria saratogana Howe & Wallace
[U.S.G.S. Prof. paper 206, Pl. 28, fig. 5 (a), (b)]
(PL. 1, FIG. 8)
SPECIMEN NO. 30/10 SSE (18)

Description: Test elongate, early portion close coiled, later uncoiled, becoming straight; 8 chambers distinctly seen; sutures curved; wall smooth, perforate; aperture terminal, radiate.

Locality: Varaguppadi ridge (10), Kulakkalnattam ridge (28), Sirukanbur ridge (25), Karai ridge (4), and Nambakkurichi ridge (20).

Remarks: This form has similarity with S. saratogana described from the Up. Cret. (Navarro age) of Gulf Coast, U.S.A.

Genus—**PSEUDOGLANDULINA Cushman, 1912**

Pseudoglandulina sp.
(PL. 1, FIG. 14)
SPECIMEN NO. 30/10 SSE (7)

Description: Test uniserial, straight with 3 chambers, the last one making a major portion of the test; sutures transverse; wall mooth, perforate; aperture terminal.

Locality: Varaguppadi ridge (10) and Nallur ridge (30).

Genus—**VAGINULINA d'Orbigny, 1826**

Vaginulina sp.
(PL. 1, FIG. 44)
SPECIMEN NO. 4/27 M (4)

Description: Test elongate, compressed, one margin usually straight, sutures curved downward, surface smooth, wall perforate, aperture terminal, radiate.

Occurrence: Terkumadevi ridge (27), Nattakkudu ridge (26), Kulakkalnattam ridge (28), Kudikkadu ridge (12), Karai ridge (4), Nambakkurichi ridge (20), Ukkalur ridge (17), Ayinapuram ridge (6), Nallur ridge (30), Uttattur ridge (19).

Remarks: Common.

Sub-family—**Lageninae**

Genus—**LAGENA Walker & Jacob, 1798**

Lagena cf. globosa Montagu
[U.S.G.S. Prof. paper 206, Pl. 39, fig. 26]
(PL. 1, FIG. 22)
SPECIMEN NO. 30/10 SSE (5)

Description: Test globose, single chambered, wall perforate, smooth, aperture terminal, radiate.

Locality: Varaguppadi ridge (10), Ukkalur ridge (17), Nambakkurichi ridge (20) and Uttattur ridge (19).

Remarks: This form has similarity with L. cf. globosa described from the Up. Cret. of Gulf Coast (Navarro, Taylor & Austin age, U.S.A.) & N.W. basin, Western Australia.

Lagena hispidi Reuss

[U.S.G.S. Prof. paper 206, Pl. 39, fig. 13]
(PL. 1, FIG. 13)
SPECIMEN NO. 30/10 (4)

Description: Test spherical, single chambered with a neck, wall perforate, surface spinose, aperture terminal at the end of the neck.

Locality: Varaguppadi ridge (10), Kulakkalnattam ridge (28), Sirukanbur ridge (25) and Nallur ridge (30).

Remarks: This form has remarkable similarity with L. hispidi described from the Up. Cret. (Navarro, Taylor & Austin age) of Gulf Coast.

Family—**ELLIPSOIDINIDAE**

Genus—**PLEUROSTOMELLA Reuss, 1860**

Pleurostomella subnodosa Reuss

[U.S.G.S. Prof. paper 206, Pl. 55, fig. 1 (a), (b)]
(PL. 1, FIG. 46)
SPECIMEN NO. 1/20 N (13)

Description: Test elongate, early chambers biserial, later chambers irregularly uniserial; eleven chambers distinct, unequal; sutures distinct, depressed; in uniserial chambers sutures are directed alternately in opposite directions; surface smooth, wall perforate; aperture at the last chamber, arc shaped, in a depressed area.

Locality: Karai ridge (4), Nallur ridge (30), Ayinapuram ridge (6), Nambakkurichi ridge (20), Varaguppadi ridge (10), Sirukanbur ridge (25) and Kudikkadu ridge (12).

Remarks: Common. It agrees closely with P. subnodosa that has been described from Taylor age of U.S. Gulf Coast.

Family—**GLOBIGERINIDAE**

Sub-family—**Globigerininae**

Genus—**GLOBIGERINA d'Orbigny, 1826**

Globigerina cretacea d'Orbigny

[Jour. Pal. Vol. 17, Pl. 82, fig. 16]
(PL. 1, FIG. 26)
SPECIMEN NO. 4/27 M (5)

Description: Test trochospiral with 3 volutions; chambers globular, inflated; dorsal side with 11 chambers, ventral side with 5 chambers; sutures distinct, depressed, nearly straight; wall calcareous, perforate, surface very finely spinose; aperture large, arched, in the umbilical region.

Locality: Nallur ridge (30), Ayinapuram ridge (6), Kulakkalnattam ridge (28), Terkumadevi ridge (27).

Remarks: This sp. is particularly abundant during Up. Cret. and has been described from Up. Cret. of Gulf Coast, U.S.A. and Western Australia.

Family—**GLOBOROTALIIDAE**

Genus—**GLOBOTRUNCANA Cushman, 1927**

Globotruncana ventricosa ventricosa White

[Bul. Am. Pal. Vol. 36, no. 155, Pl. 1, fig. 5 a-c].
(PL. 1, FIG. 47)
SPECIMEN NO. 29/6 E (F)

Description: Test trochospiral with three volutions; dorsal side flat with numerous chambers; ventral side convex with six chambers; sutures curved on the dorsal side, radial and depressed on the ventral; wall calcareous, perforate, finely spinose; umbilical area large, grooved; aperture large with a continuous slightly arched, lip-like projection; periphery double-keeled.

Locality: Ayinapuram ridge (6), Nallur ridge (30), Kulakkalnattam ridge (28).

Remarks: This sp. has been described from Senonian of N. Eastern Columbia and Europe.

Globotruncana rosetta rosetta Carsey

[Bull. Am. Pal. Vol. 36, no. 155, Pl. 6, fig. 1 a-c]
(PL. 1, FIG. 30)
SPECIMEN NO. 5/28 NE (14)

Description: Test trochospiral, dorsal side with nearly flat chambers, early chambers short with radial suture, later petaloid with curved sutures, ventral side with 5 chambers; sutures radial, periphery with a single keel; wall perforate; surface more or less smooth; aperture large, with arched lip-like projection from the chambers.

Locality: Ayinapuram ridge (6), Kulakkalnattam ridge (28).

Remarks: This sp. has been described from Senonian of North-Eastern Columbia and Europe.

Family—**OPHTHALMIDIIDAE**

Sub-family—**Cornuspirinae**

Genus—**CORNUSPIRA Schultze, 1854**

Cornuspira sp.

(PL. 1, FIG. 12)
SPECIMEN NO. 30/10 SSE (1)

Description: Test planispiral, closely coiled, depressed near the centre; tubular chamber gradually increasing in size; wall smooth, coarsely perforate; aperture terminal at the end of the tube.

Locality: Karai ridge (4), Ukkalur ridge (17), Uttattur ridge (19), Nambakkurichi ridge (20), Varaguppadi ridge (10), Sirukanbur ridge (25) and Terkumadevi ridge (27).

Family— **HETEROHELICIDAE**

Sub-family—**Bolivinitinae**

Genus—**BOLIVINITA Cushman, 1927**

Bolivinita eleyi Cushman

[U.S.G.S. Prof. paper 206, Pl. 48, fig. 20 (a), (b)]

(PL. 1, FIG. 19)

SPECIMEN NO. 30/12 NNW (3)

Description: Test elongate, 6 times as long as broad; biserial; periphery flattened to slightly rounded; 14 chambers distinctly seen; sutures crescentic in shape; wall smooth, surface finely perforate; aperture not seen.

Locality: Kudikkadu ridge (12).

Remarks: This sp. has been recorded from Up. Cret. (Taylor and Austin age) of Texas Gulf Coast, U.S.

Sub-family—**Eouvigerininae**

Genus—**NODOGENERINA Cushman, 1927**

Nodogenerina sp.

(PL. 1, FIG. 10)

SPECIMEN NO. 6/30 N (19)

Description: Test short, uniserial, straight, chambers few, truncated; wall smooth, perforate; aperture terminal, circular.

Locality: Ayinapuram ridge (6), Nallur ridge (30) and Kulakkalnattam ridge (28).

Sub-family—**Gumbelininae**

Genus- **RECTOGUMBELINA Cushman, 1932**

Rectogümbelina sp.

(PL. 1, FIG. 18)

SPECIMEN NO. 6/30 N (12)

Description: Test with early portion biserial, later irregularly uniserial; chambers distinct, numerous, to some extent inflated, slightly overlapping; sutures distinct, oblique, slightly depressed; wall perforate, surface smooth; aperture terminal with a very short neck.

Locality: It has been recorded from Nallur ridge (30).

Remarks: Very rare.

Family—**BULIMINIDAE**

Sub-family—**Virgulininae**

Genus—**LOXOSTOMA Ehrenberg, 1854**

Loxostoma sp.

(PL. 1, FIG. 17)

SPECIMEN NO. 6/30 N (14)

Description: Test elongate slender, slightly tapering, greatest breadth towards the apertural end, slightly twisted, compressed; early chambers biserial, later tending to become uniserial; six chambers distinct, increasing in height towards the apertural end; later chambers inflated; sutures distinct, slightly depressed, oblique, slightly curved; surface smooth, wall perforate; aperture terminal.

Locality: It has been recorded from Nallur ridge (30).

Remarks: Very rare.

Family—**POLYMORPHINIDAE**
Sub-family—**Polymorphininae**
Genus—**GUTTULINA d'Orbigny, 1839**
Guttulina sp.

(PL. 1, FIG. 23)
SPECIMEN NO. 5/28 NE (4)

Description: Test fusiform, broadest in the middle, base somewhat rounded, acute apertural end; chambers arranged as in Quinqueloculina, slightly overlapping; sutures distinct but not depressed; wall smooth, perforate, aperture at the apical angle, indistinct.

Locality: Kulakkalnattam ridge (28).

Sub-family—**Ramulininae**
Genus—**RAMULINA Rupert Jones, 1875**
Ramulina globulifera H. B. Brady

[Foraminifera-Cushman, 4th Edition, 1950, Pl. 22, fig. 23]
(PL. 1, FIG. 24)
SPECIMEN NO. 1/20 N (11)

Description: Test with a single globular chamber with four radial tubes projected from the surface; wall and tubes spinose, perforate.

Locality: Nambakkurichi ridge (20), Uttattur ridge (19), Ayinapuram ridge (6), Kulakkalnattam ridge (28).

Remarks: Common. It has also been described from the Taylor formation, U.S. and Northwest Basin, Western Australia of Up. Cret. age.

Ramulina arkadelphiana Cushman

[U.S.G.S. Prof. paper 206, Pl. 43, fig. 4]
(PL. 1, FIG. 39)
SPECIMEN NO. 29/6. E (4)

Description: Test with irregularly elongate portions from which tubular projections extend in various directions, projections have rounded openings; wall thin, finely hispid.

Locality: Ayinapuram ridge (6).

Remarks: Very rare. It agrees closely with the species that has been described from Navarro age of U.S. Gulf Coast.

Family—**RHIZAMINNIDAE**

Genus—**BATHYSIPHON M. Sars, 1872**

Bathysiphon alexandri Cushman

[U.S.G.S. Prof. paper 206, Pl. 1, fig. 5]

(PL. 1, FIG. 31)

SPECIMEN NO. 30/10, SSE (41)

Description: Test elongate, wall thin, more or less straight; margin smooth; wall coarsely perforate; aperture at the end of the tube, elongate.

Locality: Varaguppadi ridge (10).

Remarks: This sp. has a remarkable similarity with B. alexandri described from the Up. Cret. (Austin age) of Gulf Coast, U.S.A.

Bathysiphon taurinensis Sacco

[U.S.G.S. Prof. paper 206, Pl. 1, fig. 3]

(PL. 1, FIG. 32)

SPECIMEN NO. 4/25 S (28)

Description: Test elongate, more or less straight, margin very irregular, wall agglutinated, coarsely perforate, aperture at both ends of the tube.

Locality: Sirukanbur ridge (25).

Remarks: This sp. has a close resemblance with B. taurinensis of Up. Cret. (Austin age) of Gulf Coast, U.S.A.

Family—**ASTRORHIZIDAE**

Genus—**Rhabdammina M. Sars, 1809**

Rhabdammina sp.

(PL. 1, FIG. 34)

SPECIMEN NO. 4/25 S (27)

Description: Test elongate, slightly curved, has a branching tendency; wall agglutinated, coarsely perforate; aperture at both ends.

Locality: Sirukanbur ridge (25).

Family—**HYPERAMMINIDAE**

Sub-family—**Hyperammininae**

Genus—**SACCORHIZA Eimer & Fickert, 1899**

Saccorhiza (?) sp.

(PL. 1, FIG. 33)

SPECIMEN NO. 4/25 S (29)

Description: Test slightly, curved margin irregular; wall agglutinated coarsely perforate; aperture at both ends.

Locality: Sirukanbur ridge (25).

Family—**TEXTULARIIDAE**

Sub-family—**Textulariinae**

Genus—**TEXTULARIA Defrance, 1824**

Textularia sp.

(PL. 1, FIG. 20)
SPECIMEN NO. 5/28 SSW (31)

Description: Test elongate, biserial with zig-zag line between the chambers on the middle; chambers simple; wall arenaceous, perforate; surface more or less smooth; aperture not seen.

Locality: Kulakkalnattam ridge (28) and Nallur ridge (30).

Family—**ANOMALINIDAE**

Sub-family—**Anomalininae**

Genus—**ANOMALINA d'Orbigny, 1826**

Anomalina ammonoides (Reuss) Chapman

[U.S.G.S. Prof. paper 206, Pl. 63, fig. 11 a-c]
(PL. 1, FIG. 27)
SPECIMEN NO. 30/10 SSE (21)

Description: Test compressed, slightly trochospiral; dorsal side less involute than the ventral one; chambers numerous; sutures indistinct on the ventral side; wall smooth, perforate; aperture peripheral, a low arched opening.

Occurrence: Sirukanbur ridge (25).

Remarks: Abundant. This sp. is very similar to A. ammonoides (Reuss) Chapman described from the Up. Cret (Taylor and Austin) of the Gulf Coast, U.S.A.

Anomalina clementina (d'Orbigny) Franky

[U.S.G.S. Prof. paper 206, Pl. 63, fig. 12 a-c]
(PL. 1, FIG. 21)
SPECIMEN NO. 4/25 S (21)

Description: Test almost planispiral, involute in character with numerous chambers; sutures on the dorsal side nearly straight; distinct on the ventral side, slightly curved; wall smooth, perforate; aperture peripheral, slit-like.

Occurrence: Sirukanbur ridge (25), Uttattur ridge (19), Ukkalur ridge (17), Nambakkurichi ridge (20), Karai ridge (4) and Nallur ridge (30).

Remarks: Very common. This form has a close similarity with A. clementina (d'Orbigny) Franky described from the Up. Cret. (Navarro and Taylor) of the Gulf Coast, U.S.A.

Anomalina henbesti Plummer

[U.S.G.S. Prof. paper 206, Pl. 64, fig. 2 a-c]
(PL. 1, FIG. 25)
SPECIMEN NO. 4/25 S (37)

Description: Test trochospiral, ventral side more involute than the dorsal one; chambers numerous, inflated; wall smooth, perforate; aperture peripheral, not distinctly seen.

Locality: Sirukanbur ridge (25), Kulakkalnattam ridge (28).

Remarks: Common. This form is very similar to A. henbesti Plummer described from the Up. Cret. (Navarro & Taylor) of the Gulf Coast, U.S.A.

Family—**VERNEULINIDAE**
Genus—**CLAVULINOIDES Cushman, 1936**
Clavulinoides sp.
(PL. 1, FIG. 36)
SPECIMEN NO. 30/10 SSE (17)

Description: Test more or less elongate, gradually constricted towards the initial end with a median ridge at one side; 5 chambers distinct; sutures crescentic in shape; surface smooth, wall perforate; aperture terminal, rounded.

Occurrence: Varaguppadi ridge (10), Kulakkalnattam ridge (28), Sirukanbur ridge (25).

Remarks: Common.

Genus—**GAUDRYINELLA Plummer, 1931**
Gaudryinella sp.
(PL. 1, FIG. 43)
SPECIMEN NO. 4/25 S (6)

Description: Test elongate, narrow; in the early stage triserial, later biserial; chambers numerous; surface rough, wall coarsely perforate.

Occurrence: Sirukanbur ridge (25) and Kudikkadu ridge (12).

Family—**ROTALIIDAE**
Sub-family—**Discorbinae**
Genus—**GYROIDINA d'Orbigny, 1826**
Gyroidina beisseli White
[U.S.G.S. Prof. paper 206, Pl. 58, fig. 11 a-c]
(PL. 1, FIG. 40)
SPECIMEN NO. 5/28 SW (9)

Description: Test trochospiral; dorsal side flat, ventral side slightly conical; chambers numerous; sutures radial, indistinct; wall finely perforate, surface smooth; umbilicus small; aperture an arched opening at the base of the apertural face on the ventral side.

Occurrence: Kulakkalnattam ridge (28) Sirukanbur ridge (25) and Nallur ridge (30).

Remarks: Abundant. This form has a close similarity with G. beisseli White described from the Up. Cret of Mexico.

Sub-family—**Rotaliinae**
Genus—**ROTALIA Lamarck, 1804**
Rotalia sp.
(PL. 1, FIG. 42)
SPECIMEN NO. 22/43 W (C)

Description: Test trochospiral, dorsal side slightly conical, ventral one nearly flat; chambers numerous; sutures limbate, curved on the dorsal side, truncated near the umbilicus on the ventral side; surface smooth, wall perforate; aperture not seen.

Occurrence: Panangur ridge (43).

Remarks: Rare.

Family—**NONIONIDAE**

Genus—**NONIONELLA Cushman, 1926**

Nonionella sp.

(PL. 1, FIG. 36)

SPECIMEN NO. 30/10 SSE (25)

Description: Test slightly trochospiral; chambers numerous; ventral side with an elongate lobe from the periphery to the umbilicus; wall perforate, surface smooth; aperture peripheral, slit-like.

Occurrence: Varaguppadi ridge (10).

Remarks: Rare.

Family—**PLANORBULINIDAE**

Genus—**PLANORBULINA d'Orbigny, 1826**

Planorbulina sp.

(PL. 1, FIG. 37)

SPECIMEN NO. 30/12 NNW (4)

Description: Test very small, trochospiral, closely coiled; chambers numerous, globular; sutures distinct; ventral side with 5 chambers; wall coarsely perforate, surface smooth.

Occurrence: Kudikkadu ridge (12).

Remarks: Common.

Family—**CHILOSTOMELLIDAE**

Sub-family—**Allomorphinellinae**

Genus—**PULLENIA Parker & Jones, 1862**

Pullenia sp.

(PL. 1, FIG. 28)

SPECIMEN NO. 4/25 S (44)

Description: Test planispiral, completely involute; periphery broadly rounded; sutures slightly curved; wall perforate, surface smooth; apertural face peripheral, aperture not distinct.

Occurrence: Sirukanbur ridge (25).

Remarks: Rare.

Bibliography

Bagg, R. M. The Cretaceous Foraminifera of New Jersey, Bull. 88, 1898. U. S. Geol. Surv.

Blanford, H. F. Cretaceous and other rocks of South Arcot and Trichinopolly districts. Memoir 4, 1862, Geol. Surv. of India.

Crespin, I. Upper Cretaceous Foraminifera from the North-west basin, West Australia. Jour. Paleo. Vol. 12, No. 4, 1938, p. 391-395.

Cushman, J. A. Foraminifera, Their classification and Economic Use, 4th Edn., 1954. Harvard Univ. Press.

„ Up. Creta. foraminifera of the Gulf Coast region of the U.S., U.S.G.S. Prof. Paper 206, 1946, p. 1-241.

d'Orbigny Soc. Géol. France, Mém. 1st Ser., Vol. 4, p. 14 ; pl. 1 fig. 5, 1840.

Gandolfi, R. The Genus Globotruncana in North-eastern Columbia. Bull. Amer. Palaeo. Vol. 36, 1955, No. 155.

Glaessner, M. F. Principles of Micropalaeontology, 1947. Melbourne Univ. Press.

Jacob, K. & Sastry, M. V. A. On the occurrence of Globoturncana in the Uttattur stage of the Trichinopoly district, S. India. Science & Culture. Vol. 16, No. 6, 1951.

Kossmat, F. On the importance of the Cretaceous rocks of South India in estimating the geographic conditions during later Cretaceous times. Rec. 28, 1895, Geol. Surv. India.

Morrow, A. L. Foraminifera and Ostracoda from the Upper Cretaceous of Kansas Jour. Palaeo. Vol. 8, No. 2, 1934.

Pascoe, E. H. A Manual of Geology of India and Burma, 3rd Edn. Vol. 2, 1959.

Plummer, H. J. Some cretaceous foraminifera in Texas. Bull. No. 3101, 1931, Texas Univ.

Reuss, A. E. Akad. Wiss. Wien, Math-naturwiss. Kl., Sitzungsber, Vol. 40, p. 192 ; pl. 4, fig. 7, 1860.

„ Verstein, böhn. Kreideformation, pl. 1, p. 26 ; pl. xiii, fig. 16, 1845.

Stoliczka, F. Cretaceous Fauna of South India. Palaeontologia Indica, Old Series, Vols. 1 to 4, 1861-1873.

Explanation of Plate I

1. Robulus münsteri Cushman (a) side view, (b) apertural view
2. R. pseudo-secans Cushman (a) side view, (b) apertural view
3. R. stephensoni Cushman (a) side view, (b) apertural view
4. R. pondi Cushman (a) side view, (b) apertural view
5. Marginulina jarvisi Cushman
6. Dentalina gracilis d'Orbigny
7. Frondicularia arkadelphiana Cushman
8. Saracenaria saratogana Howe & Wallace
9. Saracenaria triangularis (d'Orbigny) Cushman & Church
10. Nodogenerina sp. (a) side view, (b) apertural view
11. Nodosaria affinis Reuss
12. Cornuspira sp. (a) side view, (b) apertural view
13. Lagena hispidi Reuss
14. Pseudoglandulina sp.
15. Frondicularia archiaciana d'Orbigny
16. Frondicularia goldfussi Reuss
17. Loxostoma sp.
18. Rectogümbelina sp.
19. Bolivinita eleyi Cushman
20. Textularia sp.
21. Anomalina clementina (d'Orbigny) Franky
    (a) dorsal view, (b) ventral view, (c) apertural view
22. Lagena cf. globosa Montagu
23. Guttulina sp.
24. Ramulina globulifera H.B. Brady
25. Anomalina henbesti Plummer (a) dorsal view, (b) ventral view, (c) apertural view
26. Globigerina cretacea d'Orbigny (a) dorsal view, (b) ventral view
27. Anomalina ammonoides (Reuss) Cushman
    (a) dorsal view, (b) ventral view, (c) apertural view
28. Pullenia sp. (a) side view, (b) apertural view
29. Lenticulina sp.
30. Globotruncana rosetta rosetta Carsey
    (a) dorsal view, (b) ventral view, (c) peripheral view
31. Bathysiphon alexanderi Cushman
32. B. taurinensis Sacco
33. Saccorhiza sp.
34. Rhabdammina sp.
35. Nonionella sp. (a) dorsal view, (b) ventral view, (c) apertural view
36. Clavulinoides sp.
37. Planorbulina sp.

38. Marginulina curvatura Cushman
39. Ramulina arkadelphiana Cushman
40. Gyroidina beisseli White
    (a) dorsal view, (b) ventral view, (c) apertural view
41. Marginulina navarroana Cushman
42. Rotalia sp. (a) dorsal view, (b) ventral view
43. Gaudryinella sp.
44. Vaginulina sp.
45. Marginulina texasensis Cushman
46. Pleurostomella subnodosa Reuss
47. Globotruncana ventricosa ventricosa White
    (a) dorsal view, (b) ventral view, (c) peripheral view.

Explanation of Fig. I

Geological map of the area around Uttattur.

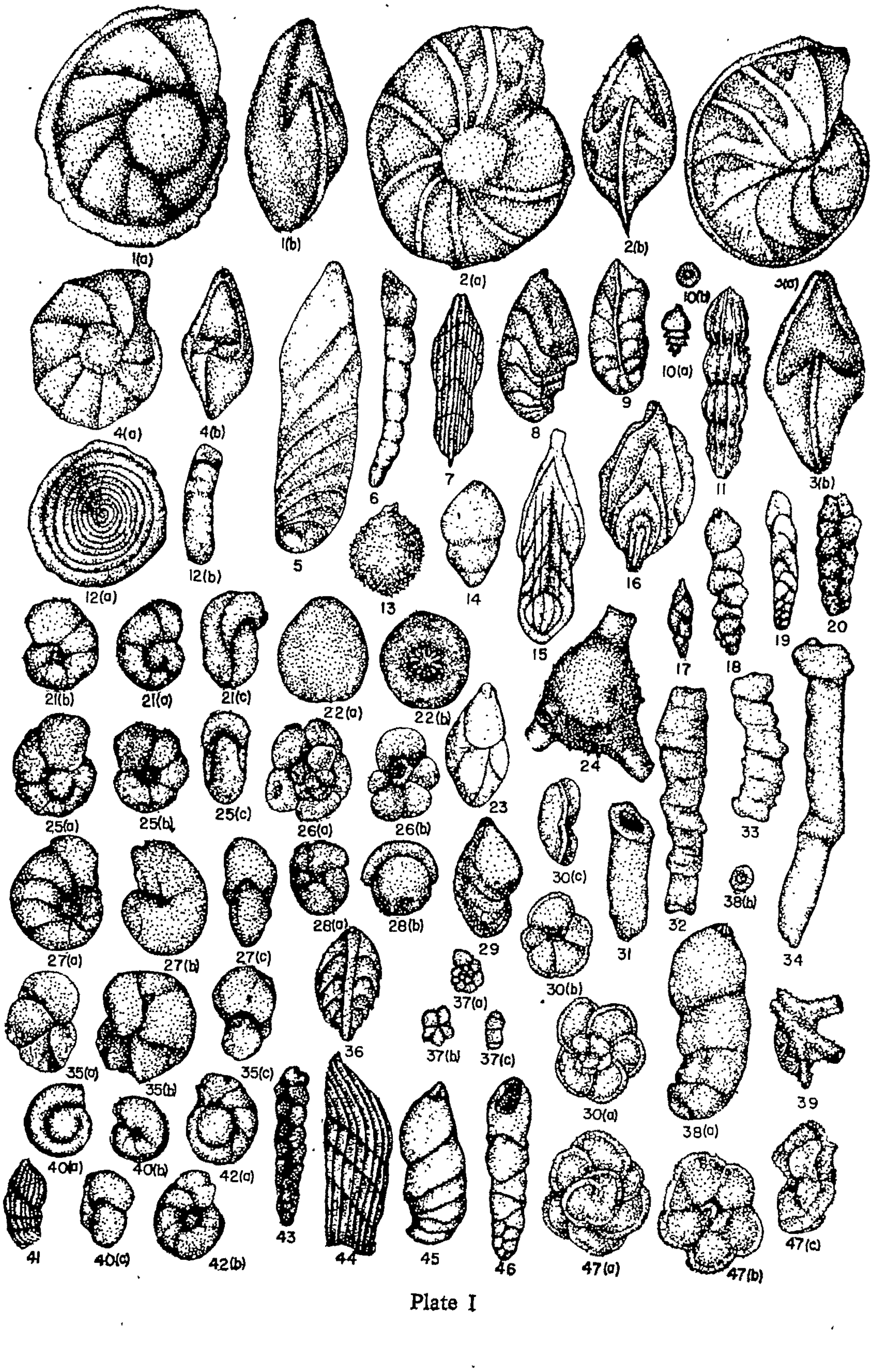

1(a)
1(b)
2(a)
2(b)
3(a)
4(a)
4(b)
5
6
7
8
9
10(a)
10(b)
11
3(b)
12(a)
12(b)
13
14
15
16
17
18
19
20
21(b)
21(a)
21(c)
22(a)
22(b)
23
24
25(a)
25(b)
25(c)
26(a)
26(b)
27(a)
27(b)
27(c)
28(a)
28(b)
29
30(c)
30(b)
31
32
33
34
38(b)
35(a)
35(b)
35(c)
36
37(a)
37(b)
37(c)
30(a)
38(a)
39
40(a)
40(b)
42(a)
41
40(c)
42(b)
43
44
45
46
47(a)
47(b)
47(c)

Plate I

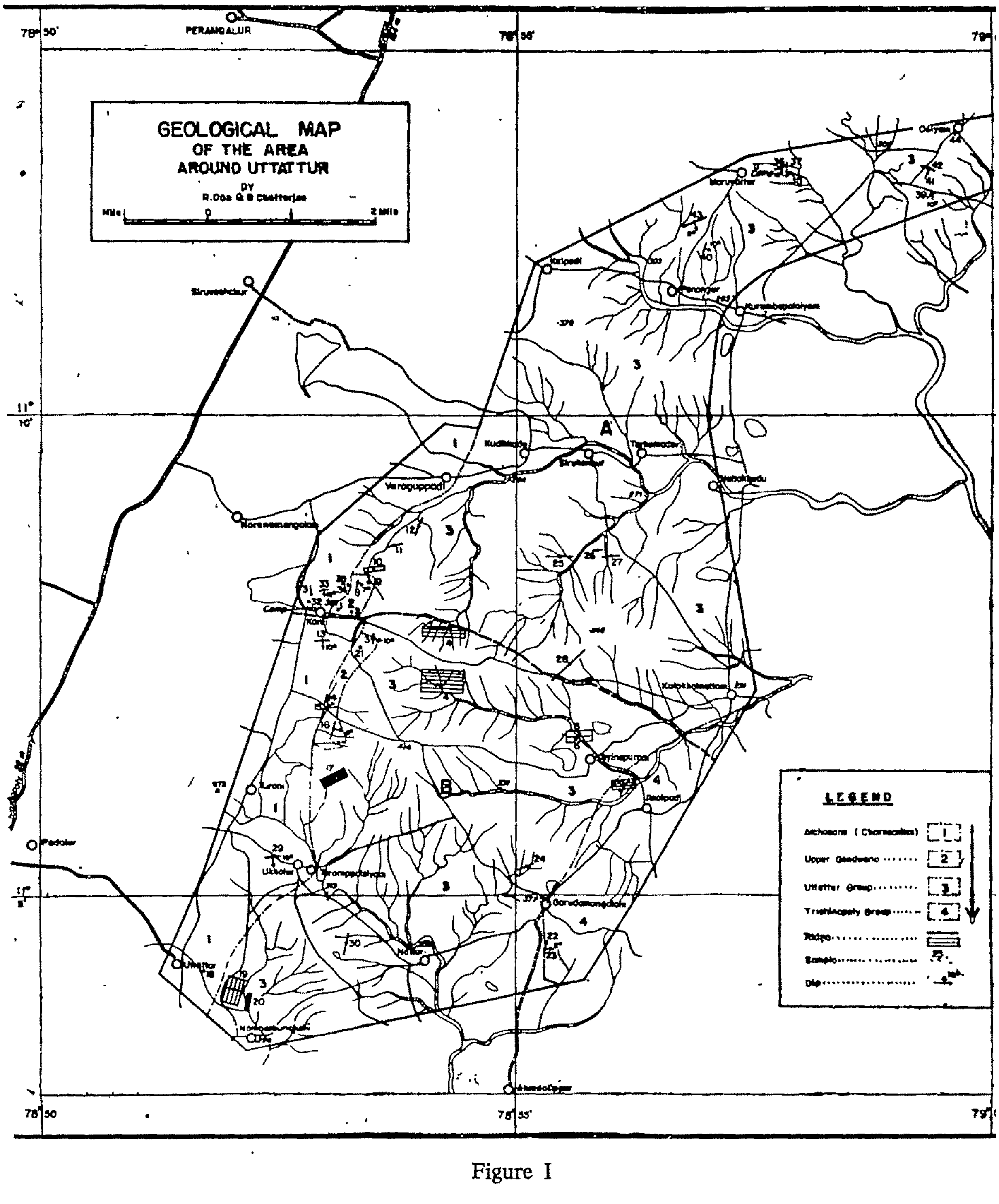

GEOLOGICAL MAP
OF THE AREA
AROUND UTTATTUR
BY
R. Das & B Chatterjee
Mile 0 1 2 Mile
LEGEND
Archaean (Charnockites) 1
Upper Gondwana 2
Uttattur Group 3
Trichinopoly Group 4
Ridge
Sample
Dip
78° 50'
78° 55'
79°
11° 10'
11° 5'
PERAMBALUR
Siruvachur
Varaguppadi
Karai
Camp
Uttattur
Padalur
Garudamangalam
Kulakkanattam
Alundalippur
A
B
1
2
3
4

Figure I

CAL
UNIVERSITY
CENTRAL
LIBRARY

BULLETIN
OF THE
GEOLOGICAL, MINING AND METALLURGICAL
SOCIETY OF INDIA

No. 32 | NOVEMBER, 1964

A Note on Polospores from Tura Formation, Simsang River Section, Assam[1]*

(Figs. 1-15)

By
Debashis Banerjee

ABSTRACT

Some samples collected from the Tura Formation of Simsang River Section, Assam (90°35' to 90°45' Lat : 25°10' to 25°25' Long) have been analysed for palynological studies. The different types of polospores recorded have been described. The age of the samples have been indicated as Lower Tertiary (possibly Eocene) on the basis of the polospore assemblage.

INTRODUCTION

Some samples were collected from Tura and Surma Formations of Simsang River Section, Assam (90°35' to 90°45' Lat : 25°10' to 25°25' Long) by the Geologists of the Oil & Natural Gas Commission during the field season 1958-59. The results of the palynological studies on Surma samples (Miocene) were presented in a paper (Banerjee, 1961) at the thirteenth annual scientific meeting of the Paleobotanical Society of India at Lucknow. The results on the Tura samples are briefly reported here.

---

[1] Published with permission of Director of Geology, Oil & Natural Gas Commission. The views expressed are those of the author only and not necessarily of the organisation for which he is working.

* Read on 27th November, 1963.

MATERIALS & METHODS

The samples are mostly clays, a few being shales and coal. These were macerated in HNO_3 and KOH. Treatment with HF was also done wherever necessary. The polospores were separated by floating in a heavy liquid of sp. gr. 2.3 and mounted in glycerine jelly. The different types have been classified into artificial genera and subgenera following the scheme proposed by Van der Hammen (1956) and are enumerated as under.

DESCRIPTION OF POLOSPORE TYPES

Verrumonoletes V. d. Ham. (1956)—Spores monolete, medium to large, verrucate ; exine thin ; verrucae variable in size, irregularly distributed ; aperture rather short ; 44-60 μ X 28-36 μ in size. Referable to Polypodiaceae. Not common. Fig. 2.

Similar form : *Polypodiaceaesporites tuberculensis* gen. et sp. nov. Baksi, 1962, Pl. 3, fig. 4, Simsang Palynological Zone III (Oligocene), Assam.

Retimonoletes V. d. Ham. (1956)—Spores monolete, medium, reticulate ; exine thin ; reticulum fine ; aperture rather short ; 36-40 μ X 24-32 μ in size. Referable to Polypodiaceae. Common. Fig. 3.

Psilatriletes V. d. Ham. (1956)—Spores trilete, medium, psilate ; exine about 2μ thick ; tetrad scar straight, slightly open, extending almost to the apices ; sub-triangular, sides rounded at apices : 32-44 μ X 28-36 μ in size. (cf. Polypodiaceae). Common. Fig. 4.

Psilamonocolpites V. d. Ham. (1956)—Grains monocolpate, medium, psilate ; exine about 2μ thick ; aperture broad ; 32 μ X 20 μ in dimension. Possibly belongs to Palmae. Common. Fig. 1.

Similar form : *Palmaepites eocenica* sp. nov. Biswas, 1962, Pl. VI. fig. 26, Tura Formation of Tura-Dalu Road Section, Assam.

Scabramonocolpites V. d. Ham. (1964)—Grains monocolpate, medium, finely scabrate ; exine thin ; aperture extending almost the whole length of the grain ; 28-32 μ X 20-24 μ in size. Parentage unknown. Rare. Fig. 5.

Triporites V. d. Ham. (1954)

Scabratriporites V. d. Ham. (1956)—Grains triporate, medium, scabrate ; exine thin ; 28 μ in diameter. (cf. Tiliaceae). Rare. Fig. 6. (Polar view).

Tricolpites Erdtman (1947)

Psilatricolpites V. d. Ham. (1956)—Grains tricolpate, small, psilate, exine thin ; 24 μ X 16 μ in size. Parentage not known. Rare. Fig. 7 (Polar view, slightly oblique).

Retitricolpites V. d. Ham. (1956)—Grains tricolpate, large, reticulate ; three lobed, lobes deep, broad, gradually tapering towards the centre ; reticulum thick ; 50 μ in diameter. Parentage unknown. Not common. Fig. 15 (Polar view).

Similar form : *Tricolpate* Type No. 22. Rao & Vimal, 1952, Pl. XVIII, fig. 13, Eocene, Bikaner.

Tricolporites Erdtman (1947)

Psilatricolporites V. d. Ham. (1956)—Grains tricolporate, medium, psilate ; exine about 2 μ thick ; colpi thick, about twice the thickness of the exine, each with a pore at the equatorial region ; pores lalongate ; 32 μ X 28 μ in size. Parentage unknown. Rare. Fig. 8 (Equatorial view).

Bacutricolporites V. d. Ham. (1956)

Sp. A—Grains tricolporate, medium, baculate ; exine rather thin ; baculae small and densely crowded, individual bacula difficult to trace ; colpi thick, each with a pore at the equatorial region ; pores lalongate ; 36 μ X 32 μ in size. Parentage not known. Very common. Fig. 9 (Equatorial view).

Sp. B—Grains tricolporate, medium, baculate ; baculae densely arranged, about 1.5 μ high ; exine about 3 μ thick ; colpi thick, deep, each with a pore ; 36 μ in diameter. Referable to Caprifoliaceae (cf. *Viburnum* sp.). Very common. Fig. 10 (Polar view).

Verrutricolporites V. d. Ham. (1956)—Grains tricolporate, medium, verrucate ; colpi protruding out in a radiating fashion, each with a pore at the end ; exine about 2 μ thick ; 66 μ in diameter. Possibly referable to Onagraceae. Rare. Fig. 11 (Polar view).

Similar form : Pl. 3, figs. 2, 3, Kuyl, Muller and Waterbolk, 1956, Lr. Tertiary, Germany.

Syncolporites V. d. Ham. (1954)—Grains syncolporate, small, scabrate ; Colpi three, united at the polar region, each with a pore ; exine thin ; 24 μ in diameter. Possible affinity to Myrtaceae. Rare. Fig. 12 (Polar view).
Similar form : *Syncolporipites* sp. Pl. VI, fig. 30. Biswas, 1962, Referred to Gentianaceae, Tura Formation of Tura-Dalu road Section, Assam.

Stephanocolpites V. d. Ham. (1954)—Grains stephanocolpate, medium, baculate ; colpi six, short ; exine about 2. 5 μ thick ; 36 μ in diameter. Referable to Fagaceae (cf. *?Nothofagus* sp.). Very common, Figs. 13, 14 (Polar view, oblique).

Similar forms : *Hexacolpate* Type No. 31, Pl. XVIII, fig. 25. Rao & Vimal, 1952, Eocene, Bikaner. *Hexacolpites spm*. 4, Pl. VIII, fig. 30. Vimal, 1952, Eocene, Dandot. (?) *Hexacolpopites* sp. Pl. XIII, fig. 46. Biswas, 1962, Sylhet Limestone Formation of Um Sohryngkew River Section, Assam.

CONCLUSION

Some of the forms recorded here are recorded from Lr. Tertiary sediments by other workers from various areas. These have been indicated alongwith the descriptions. Most of the forms described here are absent in the Surma samples. The dominant forms in the Surma are either poorly represented or absent in the Tura. Polospore assemblage recorded in these samples from Tura is thus indicative of Lower Tertiary (possibly middle to upper Eocene) age.

Ghosh (1954) worked out the details of the Tura Sandstone stage of the Garo Hills. He correlated these beds of the Simsang section with the Lower and Middle or only the Middle Sylhet Limestone and Sandstone stage of the Um Sohryngkew section. On microfaunal evidence, the Sylhet Limestone and Sandstone stage is considered to be of Eocene age. Biswas (1962) has indicated a Lower to Middle Eocene age for the formation.

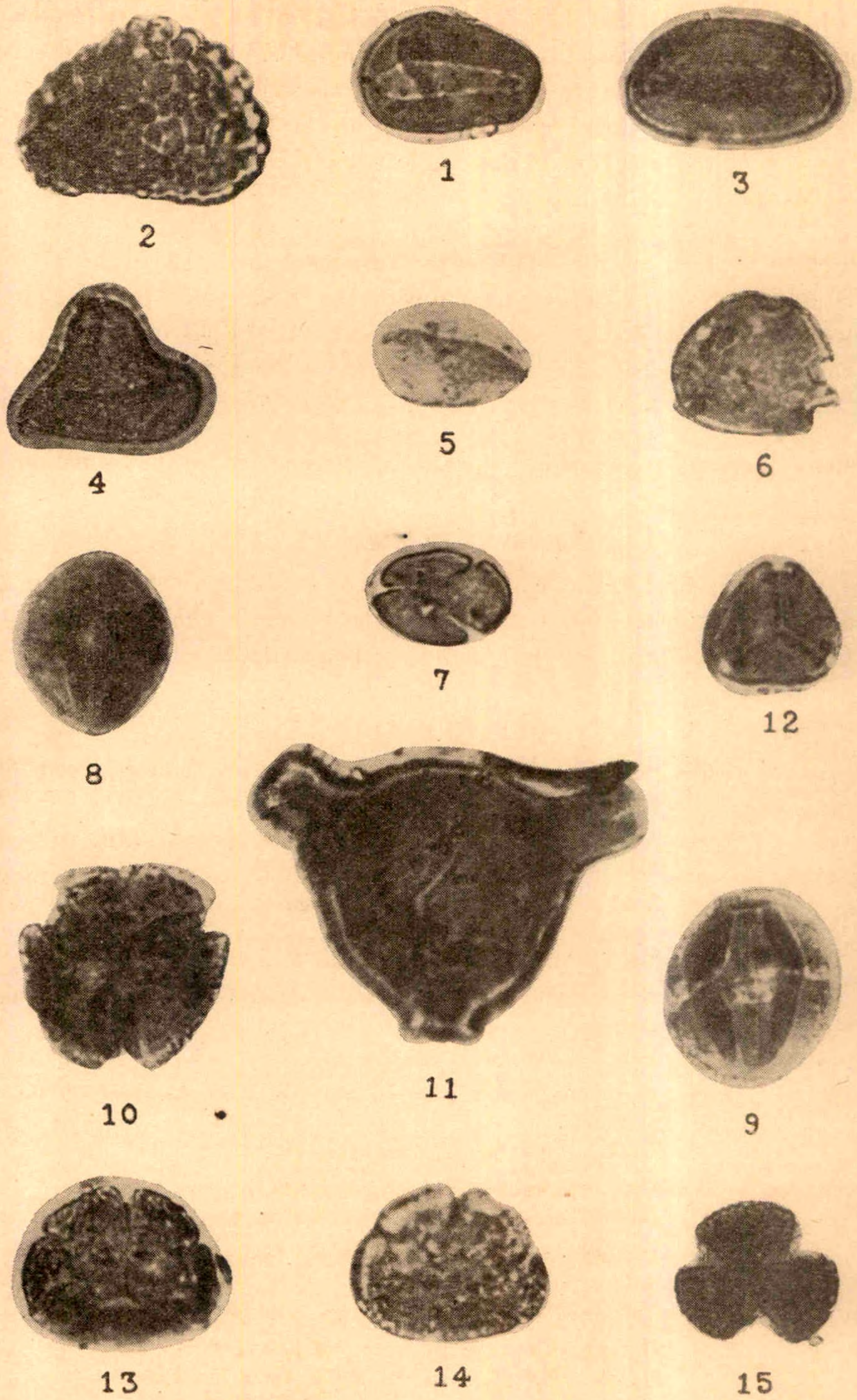
The microfloral studies corroborate the possible Eocene age for the formation.

ACKNOWLEDGEMENTS

Thanks are due to Shri P. K. Chandra and Shri D. N. Basu, Geologists, for collecting the samples and supplying other particulars. The valuable guidance received from Shri A. K. Ghosh, Palynologist (Sr.), is gratefully acknowledged.

REFERENCES

Baksi, S.K.	(1962)	Palynological investigation of Simsang River Tertiaries, South Shillong Front, Assam. *Bull. Geol. Min. Met. Soc. India*, No. 26.
Banerjee, D.	(1964)	A note on the microflora from the Surma (Miocene) of Garo Hills, Assam. *Bull. Geol. Min. Met. Soc. India*, No. 29.
Biswas, B.	(1962)	Stratigraphy of the Mahadeo, Langpar, Cherra and Tura Formations, Assam, India. *Bull. Geol. Min. Met. Soc. India*, No. 25.
Erdtman, G.	(1947)	Suggestions for the classification of fossil and recent pollen grains and spores. *Sven. Bot. Tid.*, *Bd.* 1, pp. 104—114.
Ghosh, A.M.N.	(1954)	The Tura Sandstone stage of the Garo Hills—its possible stratigraphical position. *Rec. G.S.I.*, *vol.* 83, pt. 2, pp. 423—444.
Hammen, T. Van der.	(1956)	A palynological systematic nomenclature. *Boletin Geologico, Tomo* IV, nos. 2—3, pp. 63—101.
Kuyl, O.S., Muller, J. & Waterbolk, H.T.	(1956)	The application of palynology to Oil Geology with special reference to Western Venezuela. *Geologie en Mijnbouw*, N.S. 17, no. 3, pp. 49—75.
Rao, A.R. & Vimal, K. P.	(1952)	Tertiary pollen from lignites from Palana (Eocene), Bikaner. *Proc. Nat. Inst. Sci. India*, vol. XVIII, no. 6, pp. 595—601.
Vimal, K. P.	(1952)	Spores and pollen from Tertiary lignites from Dandot, West Punjab (Pakistan). *Proc. Indian Acad. Sci.*, vol. XXXVI, no. 4, sec. B, pp. 135-147.



Figs. 1—15. Polospores from Tura Formation of Simsang River Section, Assam.

EXPLANATION OF PLATE

All photographs are from untouched negatives, magnified 600 times app.

Fig. 1.	*Psilamonocolpites*
Fig. 2.	*Verrumonoletes*
Fig. 3.	*Retimonoletes*
Fig. 4.	*Psilatriletes*
Fig. 5.	*Scabramonocolpites*
Fig. 6.	*Scabratriporites*
Fig. 7.	*Psilatricolpites*
Fig. 8.	*Psilatricolporites*
Fig. 9.	*Bacutricolporites sp.* A.
Fig. 10.	*Bacutricolporites sp.* B.
Fig. 11.	*Verrutricolporites*
Fig. 12.	*Syncolporites*
Fig. 13.	*Stephanocolpites*
Fig. 14.	Same grain as above.
Fig. 15.	*Retitricolpites*

CALCUTTA UNIVERSITY CENTRAL LIBRARY

BULLETIN
OF THE
GEOLOGICAL, MINING AND METALLURGICAL
SOCIETY OF INDIA

No. 33 | APRIL, 1965

A Note on Upper Cretaceous Microfauna from the Middle Andaman Island*

(Fig. 1 and Plate I)

By

D. K. Guha and Madan Mohan**

The existence of Pre-Tertiary sedimentary sequence in Andaman Islands was recorded by G. H. Tipper in 1911. He recognised a group of red and yellow jaspers, quartzites and pink & white porcellanic limestones, sometimes occurring as isolated exposures in the Eocene and occasionally in association with the Serpentine Series. He regarded these beds as belonging to an older series from their mode of occurrence and mentioned that the porcellanic limestone is identical with the "Lower Cretaceous" limestone (Parh Limestone, now known to be Upper Cretaceous) of Baluchistan. He assigned an Upper Cretaceous (or Pre-Upper Cretaceous) age tentatively, from the occurrence of jasper-pebbles with fragments of serpentine, in these beds.

E. R. Gee, (1926) recognised two stratigraphical units in Middle Andaman Island.

1. The Eocene sedimentaries, and
2. The Serpentine Series, probably of Cretaceous age.

---

[*] Read on 13. 7. 64. Published by the kind permission of Director of Geology, Oil and Natural Gas Commission.

[**] Geologists, Oil and Natural Gas Commission.
The views expressed in the present paper are of the authors and not necessarily of the Oil and Natural Gas Commission.

In addition, he observed several small out-crops, of probably more recent limestones in the north of the Island. Within the Serpentine Series, he includes older sedimentary beds and grouped them into four prominent rock types: (a) Jasper, (b) Porcellanic Limestone, (c) Quartzites and (d) Calc-gneisses. He did not specifically comment on the age of these beds.

G. de P. Cotter, (1938) reported the occurrence of Cretaceous rocks underlying the Eocene strata in the Andaman Islands.

K. Jacob, (1954) examined Radiolarian Cherts from a locality about 8 miles south of Port Blair near Brooksabad in South Andaman Island, collected by M. C. Poddar during the year 1950-51. These cherts were found associated with ultramafic intrusives in the older sedimentaries and have been assigned to Upper Cretaceous or early Eocene age by Jacob, in view of the association of the rock types and the fair similarity of the contained Radiolaria in cherts of the Himalayan and the Andaman region.

Y. Nagappa, (1959) opined that the correlation of the porcellanic limestone to Parh Limestone, as suggested by Tipper, is quite reasonable, though lacking in fossil evidence. However, similar porcellanic limestone occurring between Prome and Tangup in the southern part of the Arakan Range (collected by Lehner) were found to contain bi- and tricarinate types of *Globotruncana*. The authors have examined the samples collected from the localities of (a) Chandbagh Nala (92° 52′·20″ : 12° 34′), 3¼ miles north of Bumlungta, (b) 3 miles, N. 30° W. from Chand bagh Nala locality (92° 51′ 15″ : 12° 36′ 15″) and (c) 3 miles E. 10°S. from Kadamtala, (92° 49′ 18″ : 12° 20′ 24″), in Middle Andaman Island. (Text. fig. 1). The samples from (a) and (b) comprise of grey to bluish grey and dark grey, hard, calcareous clays and claystones and have been collected from the argillaceous sequence overlying the older sedimentaries. The fauna obtained from the locality includes—*Bathysiphon* sp., *Hyperammina* sp., *Trochamminoides* sp., *Cribrostomoides* ? *trinitatensis*, *Textularia* sp., ? *Pseudogaudryinella* sp., *Sigmoilina* sp., *Cornuspira* sp., *Robulus* sp., *Lenticulina* sp., *Marginulina* sp., *Dentalina* sp., *Nodosaria* sp., *Pseudoglandulina* sp., *Lagena* sp., *Nonion* sp., *Guembelina globulosa*, *Gumbelitria* sp., *Bolivinitella* ? *eleyi*, *Buliminella carseyae*, *Bulimina* ? *Kickapooensis*, *Entosolenia* sp., *Bolivina* sp., *Bolivina*

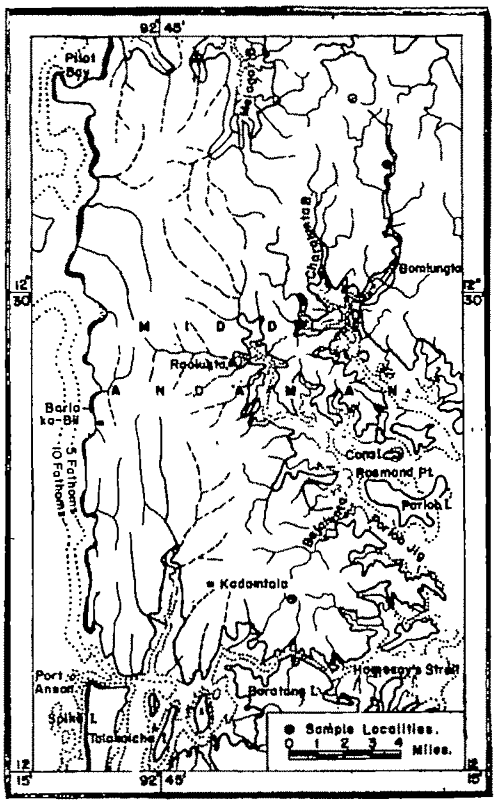


Fig. 1.

incrassata, Pleurostomella sp., *Conorbina marginata, Discorbis* sp., *Gyroidinoides* sp., *Pseudovalvulineria* sp., *Gyroidina girardana, Eponides* sp., ?*Asterigerina* sp., *Pullenia corryelli, Globigerina* sp., *Globigerina pseudobulloides, Globotruncana appenninica, Globotruncana arca, Globotruncana lapparenti, Anomalina* sp., *Cibicides* sp., & *Cytherella* sp.

The fauna is dominated by *Globotruncana*, Gumbelines and Globigerinids and mostly range in size from 0·35 mm. to 1·05 mm., while the average size of the individuals is approximately 0·5 to 0·6 mm. Speciation is not pronounced and usually two to three species represent a genus. Arenaceous formaminifera are rare, while planktonic ones dominate the assemblage. Shells are usually not ornamented but mono- and bicarinate types of *Globotruncana* occur in abundance. Tricarinate *Globotruncana* also occur rarely.

The fauna obtained from the locality (b) mainly includes—*Guembelina globulosa, Bolivina*, Rotalids & *Globotruncana arca*. The fauna is comparatively impoverished and has been represented by fewer number of genera and individuals.

Lithologically the samples from the locality (c) mainly comprise of chalky limestone, collected overlying the older sedimentaries. A more or less similar fauna, as has been obtained from the locality (a) has been recorded from the chalky limestones also. The dominant species include—*Guembelina globulosa, Gumbelitria* sp., *Bolivina* sp., *Globigerina pseudobulloides, Globotruncana arca, Globotruncana lapparenti* & *Anomalina* sp.

The fauna is represented by fewer genera but otherwise constitutes a rich assemblage, comprised by more number of individuals. Other details regarding the fauna are comparable from the fauna obtained in the locality (a). However, it is interesting to mention that the fauna obtained from the chalky limestone is comparatively smaller in size ranges than from that of (a) locality.

The presence of *Guembelina globulosa* (Ehrenberg), *Gyroidina girardana* (Reuss), *Globigerina pseudobulloides* Plummer, *Globotruncana appenninica, Globotruncana arca* Cushman and *Globotruncana lapparenti* Brotzen assign an Upper Cretaceous age to these beds. This fauna could not yet be compared with the fauna from other regions, but presumably it may not be unlike the fauna recorded from other Upper Cretaceous beds in India, Burma and Pakistan.

The present study proves beyond doubt the existence of Upper Cretaceous beds in Middle Andaman Island, but these beds overlie the older sedimentaries, the so-called Upper Cretaceous and therefore the age of the older sedimentaries needs further study.

ACKNOWLEDGEMENTS

The authors are immensely grateful to Dr. B. G. Deshpande, Director of Geology and Mr. V. V. Sastri, Superintending Geologist (Laboratories) for their kindly going through the manuscript, and to Sri P. K. Chandra and Sri M. R. Ramchandra, Geologist, for handing over their collection to enable this study.

REFERENCES

Cotter, G. de P. (1938) The geology of parts of the Minbu, Myingyan, Pakokku and Lower Chindwin districts, Burma. India, Geol. Survey, Mem , Vol : 72 pt. 1. p. 22.

Gee, E. R. (1926) The Geology of the Andaman and Nicobar Islands, with special reference to Middle Andaman Island. India, Geol. Survey, Rec., Vol. 59, pt. 2, pp. 210—216 pl. 12.

Jacob, K. (1954) The occurrence of Radiolarian cherts in association with ultramafic intrusives in the Andaman Islands and its significance in sedimentary tectonics. Rec. Geol. Survey, Vol. 83 pt. 2.

Nagappa, Y. (1959) Foraminiferal biostratigraphy of the Cretaceous-Eocene succession in the India-Pakistan-Burma region. Micropalaeontology, Vol. 5, No. 2, pp. 145—192, pls. 1—7.

Tipper, G. H. (1911) The geology of the Andaman Islands, with reference to the Nicobars India Geol. Survey. Mem., Vol. 35, pt. 4, pp. 205—206.

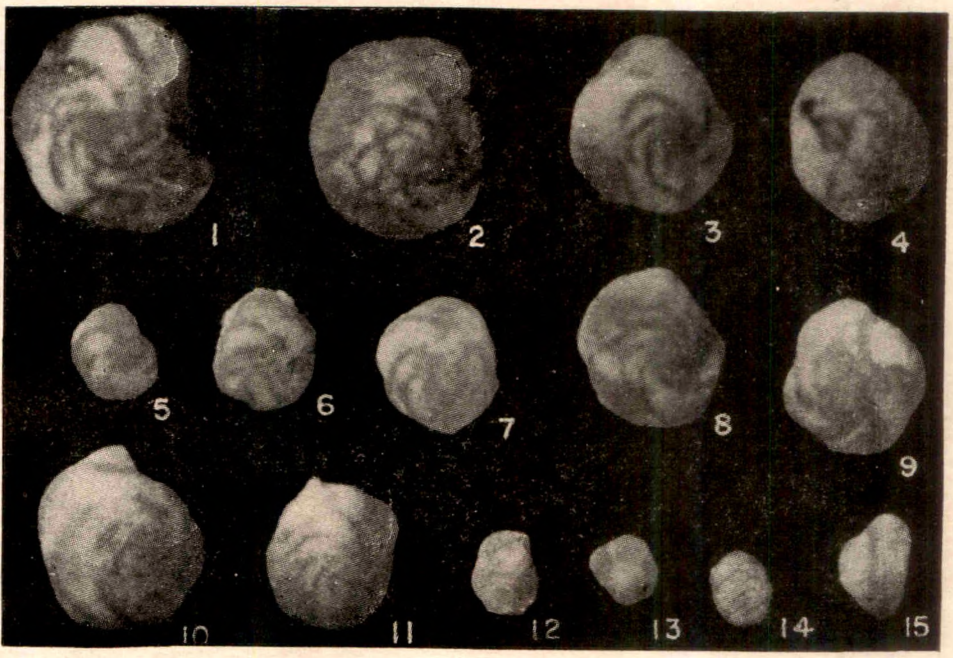
EXPLANATION OF PLATE I.

(All figures ×35)

Figs. 1—11	Globotruncana arca (Cushman), Upper Cretaceous, Kadamtala, Middle Andamans.
Figs. 12—13	Rotalids, Upper Cretaceous, Kadamtala, Middle Andamans.
Fig. 14	Bolivina sp., Upper Cretaceous, Kadamtala, Middle Andamans.
Fig. 15	Guembelina globulosa (Ehrenberg), Upper Cretaceous, Kadamtala, Middle Andamans.

D. K. Guha &
Madan Mohan

Plate I



Figs. 1-15

BULLETIN
OF THE
Geological, Mining & Metallurgical
Society of India

NO. 34 SEPTEMBER, 1965

CENTRA
LIBRAR
UNIVE

MARINE NEOGENE MICROFAUNA FROM KARIKAL, SOUTH INDIA*

(Plates 1-3)

By

*D. K. Guha, Madan Mohan, P. Kumar, Km. R. Iyengar & D. S. N. Raju***

ABSTRACT

An interesting Lower Miocene, microfaunal assemblage has been recorded in a well, below 70 metres, at Karikal. The fauna enables the division of Lower Miocene into Aquitanian and Burdigalian and has been compared with that of Gaj Beds of Sind and Western Kutch, Agate conglomerates of Surat-Broach, Quilon Beds, Baripada Beds, subcrops of Bengal Basin, Archipelago series of Andaman Islands and subsurface occurrences at Cambay and Anklesvar regions. Probable Mio-Pliocene age has been suggested for Cuddalore Sandstones.

INTRODUCTION

A deep well at Karikal, in Tanjore district, India, drilled by Oil & Natural Gas Commission, revealed about 1760 metres of the marine Tertiary sequence, above the basement. This sequence can be broadly divided into Eocene and Miocene. The lower 1050 metres characterised by *Uvigerina jacksonensis, Halkyardia minima, Hantkenina (Aragonella) lehneri, H. (Aragonella) mexicana, H. (Applinella) dumblei* and *Globorotalia aragonensis* have been assigned a Middle to Upper Eocene age. No characteristic Oligocene fauna has been recorded, but its existence is postulated as the Eocene sequence is overlain by nearly 160 metres of the poorly fossiliferous sediments, followed up by a 125 metres thick *Spiroclypeus ranjanae* rich Aquitanian sequence. This in turn underlies 355 metres thick Burdigalian sediments, characterised by *Austrotrillina howchini, Taberina malabarica, Ammonia papillosus, Miogypsina antillea, M. panamensis* etc. The uppermost 70 metres have yielded fragmentary gastropod fauna and may correspond to the "Karikal beds" of Pliocene age.

---

* Read on 5-7-65.

* Published by the kind permission of the Director of Geology, Oil & Natural Gas Commission, Dehra Dun.

** Directorate of Geology, Oil & Natural Gas Commission, Dehra Dun.

The existence of Cretaceous to Eocene sediments have been reported by various geologists from time to time, from the nearby regions in north and northwest of Karikal. The authors have also noticed the existence of typical *Globotruncana linneiana* bearing Upper Cretaceous sediments in a well at Pattukkottai, SW of Karikal, at a depth of 375 metres. These are overlain by the Eocene sediments, which in turn underlie the Cuddalore Sandstones. Another well at Pattukkottai 9 miles SE of the previous one, has revealed the presence of marine fossiliferous Miocene sequence in this region also.

KARIKAL REGION

Karikal forms eastern-most part of the Cauvery basin, which is in the southern part of the Coromandel coast, in the state of Madras (Fig. 1). It is bordered by isolated exposures of Cretaceous and Eocene in the north, northwest and west, overlain by Cuddalore Sandstones.

PREVIOUS WORK

Cossmann (1900—1910) described a rich gastropod fauna of Upper Tertiary age, from a bore hole at Karikal, from a depth of 106 metres. He considered it distinctly Pliocene (Post Pontian) in age and named these beds as "Karikal Beds".

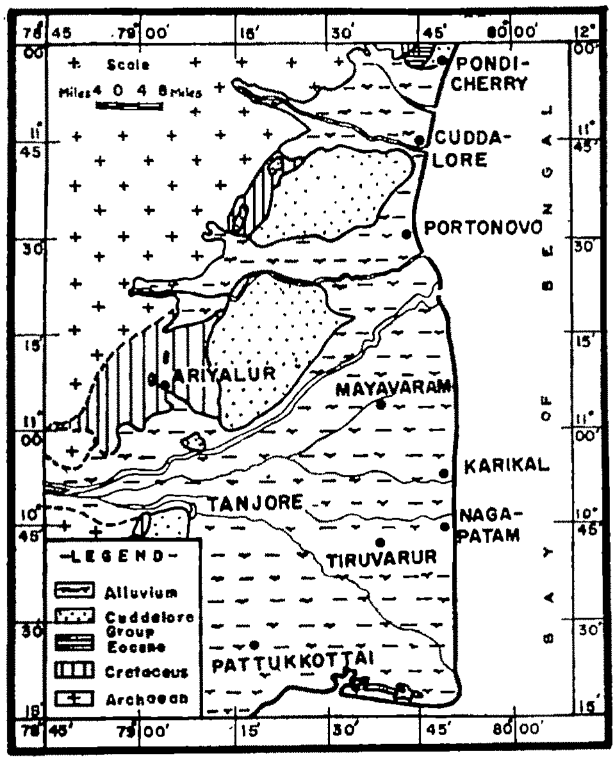


Fig. I. GENERALISED GEOLOGICAL MAP OF A PART OF CAUVERY BASIN.

As far as known to the authors, there is no other published account of the marine Miocene beds, all along the Coromandel coast.

FAUNA

An extremely rich, marine microfaunal assemblage has been recovered from the Karikal well in the sedimentary sequence, above the basement.

The lower 1050 metres of the sedimentary sequence has been assigned Middle to Upper Eocene age. Lithologically, it comprises of mainly grey to dark grey shales, occasionally pyritic with subordinate siltstones. Occasional limestone bands have been noticed in the lower part of the sequence. The microfauna is chiefly constituted by *Hyperammina* sp., *Ammodiscus* sp., *Haplophragmoides* spp., *Textularia* sp., *Verneuilina* sp., *Marssonella* sp., *Textulariella* sp., Miliolids, Lagenids, *Nummulites* sp., *Alveolina* sp , *Chiloguembelina martini*, *Plectofrondicularia* sp., *Globobulimina* sp., Bolivinids, *Uvigerina jacksonensis*, *Pleurostomella* sp., *Halkyardia minima*, *Ceratobulimina* sp., *Cassidulina* sp., *Chilostomelloides* sp., *Pullenia* sp., *Globigerina bulloides*, *Globigerinoides higginsi*, *Hantkenina (Aragonella) lehneri*, *H. (Aragonella) mexicana*, *H. (Applinella) dumblei*, *Globorotalia aragonensis*, *Discocyclina* sp., *Cytherelloidea* sp., *Bairdia* sp., *Costa* sp., *Cytheretta* sp. etc.

The lowermost 90 metres of the sediments, above the basement have yielded Alveolines and arenaceous foraminifera principally. Their exact age remains doubtful at this stage of the study, but the authors are inclined to call them as Lower Eocene in age.

The microfauna is dominated by forms, generally ranging in size from 0.3 to 1.5 mm., larger foraminifers ranging in size from 2 to 3.5 mm. are rare, except between the depths of 1583 to 1670 metres, where they appear to be common. The ornamentation, as such is fairly pronounced and includes striated, reticulate, keeled and spinose forms commonly. In the lower part, the planktons dominate the assemblage, while in the upper part of the Eocene sequence, the benthonic forms become abundant giving rise to a crowd of arenaceous foraminifera. *Uvigerina jacksonensis* marks the top of Upper Eocene at a depth of 718 metres. It is followed up by a poorly fossiliferous zone of 160 metres of calcareous sandstones and sands with minor siltstones.

The typical Lower Miocene microfauna appears at a depth of 550 metres and continues upwards for about 480 metres, leaving the top 70 metres with the fragmentary gastropod fauna. The Lower Miocene sequence is divided into Aquitanian and Burdigalian. The Burdigalian sequence is 355 metres thick, mainly comprising of grey claystones, and sandstones and sands with minor granular sands and limestones. The top is marked by the abundance of *Ammonia papillosus* along with *Quinqueloculina* sp., *Guttulina* sp., *Nonion* sp., *Elphidium indicum*, *Operculina* sp., *Bolivina* sp., *Trifarina* sp., *Discorbis* sp., *Valvulineria* sp., *Eponides* sp., *Rotalia* sp., *Asterigerina* sp., *Amphistegina* sp., *Cassidulina* sp., *Globigerina* sp., *Cibicides* sp., and *Bairdia* sp. This fauna continues consistently for 110 metres, upto the depth of 180 metres, where the typical Burdigalian microfauna makes its appearance in the well. The recovered microfaunal assemblage is added by *Textularia* sp., *Clavulinoides* sp., *Peneroplis* sp., *Loxostomum* sp., *Reussella* sp., *Gypsina globulus*, *Miogypsina antillea*, *M. panamensis*, *Aurila chaasraensis*, *Caudites* sp., *Actinocythereis tumefacentis*, *Leguminocythereis mutata*, *Echinocythereis fossularis*, *Trachyleberis spinellosa* etc. at this horizon. Except a species of *Alveolinella* which has been met with, at the depth of 195 metres, the other microfauna in general continues down in somewhat similar composition and frequency upto the depth of 270 metres. At this horizon a sudden profusion in the microfaunal complexes

has been encountered. The additional foraminifers recovered include: *Spiroloculina* sp., *Triloculina* sp., *Biloculina* sp., *Nodosaria* sp., *Elphidium* spp., *Operculina bartschi*, *Sorites* sp., *Bolivinella* sp., *Bolivina* spp., *Tubulogenerina* sp., *Bifarina* sp., *Uvigerina* sp., *Patellina* sp., *Rotorbinella* sp., *Globorotalia mayeri*, *Globigerinoides triloba triloba*, *Anomalina* sp., *Cibicides mckannai*, *Planorbulina* sp., and *Lepidocyclina* (*Nephrolepidina*) sp. The ostracodes met with at this horizon additionally are *Cytherella* sp., *C. protuberantis*, *Cytherelloidea cutchensis*, *Bairdoppilata poddari*, *Krithe* sp., *Paracypris* sp., *Cytherura interposita*, *Eucytherura* sp., *Cytheretta trifurcata*, *Cytheropteron confinis*, *Miocyprideis chaudhuryi*, *Leptocythere affinis*, *Clithrocytheridea* sp., *Neomonoceratina* sp. and *Xestoleberis* sp.

This assemblage continues, reasonably unchanged in the lower depths upto 425 metres i.e., the base of the Burdigalian sequence. However, few individuals of *Austrotrillina howchini*, *Taberina malabarica* and *Suggrunda* sp. have been recovered from the basal 70 metres of the Burdigalian sequence.

The Burdigalian fauna is well developed, mostly dominated by the forms ranging in size from 0·6 to 3·5 mm. The ornamentation among few foraminifera and ostracodes is reasonably good, but the keeled and spinose forms are practically wanted. The speciation is moderate and approximately each genus at an average may have two to three species. The planktonic assemblage of the fauna is rather poor and is represented by two species of *Globigerina*, one species each of *Gypsina*, *Globigerinoides* and *Globorotalia*. The arenaceous component of the fauna is extremely poor, represented by few individuals of *Textularia* and *Clavulinoides*.

The occurrence of *Spiroclypeus ranjanae* in abundance at 425 metres, marks the top of Aquitanian in the well. The Aquitanian sequence is 125 metres thick, dominantly comprising of sandstones, sand and subordinate claystones silty in nature, with thin limestone bands above and below. *Textularia* sp., *Quinqueloculina* sp., *Spiroloculina* sp., *Robulus* sp., *Nodosaria* sp., *Lagena* sp., *Nonion* sp., *Elphidium indicum*, *Operculina* sp., *Bolivinella* sp., *Bolivina* sp., *Suggrunda* sp., *Loxostomum* sp., *Bifarina* sp., *Reussella* sp., *Uvigerina* sp., *Angulogerina* sp., *Discorbis* sp., *Eponides* sp., *Rotalia* sp., *Asterigerina* sp., *Amphistegina* sp., *Cassidulina* sp., *Cassigerinella chipolensis*, *Globigerina* spp., *Anomalina* sp., *Cibicides* sp., *Cytherella protuberantis*, *Biardia* sp., *Krithe* sp., *Leptocythere affinis*, *Eucythere* sp., *Miocyprideis chaudhuryi* & *Leguminocythereis* sp. comprise the associated microfauna in the Aquitanian sediments.

The Burdigalian fauna is comparatively richer than the Aqitanian fauna, which is dominated by *Spiroclypeus ranjanae*, ranging in size from 2 to 3·5 mm. The smaller foraminifera do not attain their full development and size comparatively, varying from 0.2 to 1 mm. The reticulate ornamentation is very well exhibited in *Spiroclypeus*, but in general the smaller foraminifera and ostracoda mostly lack good ornamentation. The arenaceous and planktonic constituents of the fauna are poorer as compared with the respective constituents of the Burdigalian fauna.

The uppermost 70 metres of the sequence predominantly claystones and granular sands with thin mantle of alluvium, encountered in the well, has yielded fragmentary gastropod fauna and may correspond to the "Karikal Beds" of Pliocene age, as referred by Cossmann.

COMPARISON

The Eocene fauna obtained from Karikal region, although correlatable with the fauna of Western Kutch, subcrops of Cambay and Anklesvar, outcrops and subcrops of Assam and subcrops of Bengal Basin, has a comparative dominance of the planktons and a paucity of larger foraminifera.

The *Nummulites* of reticulate group, which conspicuously mark the Oligocene sediments in Western India and Sind-Baluchistan are absent here. Such existence of reticulate *Nummulites* is, however, not reported from the Oligocene sediments of Bengal Basin and Assam. In the present well also, a poorly fossiliferous zone of about 160 metres encountered, overlying the Eocenes may in part be of Oligocene age. A subsequent work in this region might be helpful in solving this problem.

The Aquitanian fauna is identical with that of Kutch, although such fauna could not be recorded in the subcrops of Cambay Gulf Basin, Bengal Basin and Assam. Recently Chatterjee (I. G. C. 1964) reported the occurrence of Aquitanian sediments from Andaman Islands. He remarks, 'The Lower arenaceous zone of the Archipelago series containing *Lepidocyclina (Eulepidina) dilatata, Miogypsinoides dehharti, Miogypsina irregularis, Cycloclypeus indopacificus, C. eidae, C. posteidae, C.* cf. *guembeliana* in the lower part and *Orbulina* in association with this assmblage in the upper part is suggestive of an Aquitanian age'. Bandy (1963) opines that the *Orbulina* appears at the base of the Burdigalian and corroborated the findings of Le Roy (1948), De Napoli (1952) and Cita and Silva (1960). The authors have also critically examined the Aquitanian sediments from Kutch and have noted the abundant occurrence of *Spiroclypeus ranjanae, Miogypsinoides dehaarti* and *Gypsina globulus*, but failed to find *Orbulina* and *Miogypsina irregularis* in the Aquitanian assemblage. However, the *Orbulina* has been recorded from the Burdigalian sequence of Kutch and Andaman Islands.

The Burdigalian sediments at Karikal region contain identical fauna, as recorded from the Western Kutch and Saurashtra, bear close resemblance with the fauna from the Gaj Beds (Lower Miocene) of Sindh and Baluchistan. The Lower Miocene fauna recovered from the subcrops of Anklesvar is more or less similar, except for the occurrence of *Taberina malabarica* and *Sorites* at Karikal region. The Lower Miocene fauna from the subsurface occurrence at Cambay is rather poor both in composition and frequency. The characteristic Burdigalian foraminifera including *Austrotrillina howchini, Taberina malabarica, Sorites* sp., *Miogypsina antillea, M. panamensis* are markedly absent, but *Ammonia papillosus* and typical Lower Miocene ostracodes including *Cytherelloidea cutchensis, Leguminocythereis mutata, Actinocythereis tumefacentis* etc. are comparatively dominant.

Rao and Singh (1956) considered the Agate conglomerates of Surat-Broach region to be of Burdigalian age and to be equivalent to the Upper Gaj of Sind and Baluchistan, Upper Pegu of Burma and Tertiary f1 and f2 stages of East Indies. Bhatia and Mandwal (1957) described a rich assemblage of smaller foraminifera from these conglomerates. The fauna in general is identical to that of the Anklesvar region and lacks the typical Burdigalian foraminifera additionally present in Kutch and Karikal region.

Very similar constituted outcrop of Tertiary rocks are present on the Malabar coast near Ratanpur, at Ratnagiri underneath the laterites.

Jacob and Sastri (1951) recorded *Austrotrillina howchini* from an exposure at Padappakra, about 7 miles NE of Quilon. They (1952) also reported a rich assemblage of foraminifers, ostracodes and bryozoans from a bore hole at Chavara near Quilon. Recently Chatterjee reported the occurrence of *Miogypsina* in Quilon beds. M. C. Ahluwalia of O. N. G. Commission, Dehra Dun (1959) examined the microfauna obtained in the bore hole near Sakthi-Bulangava, near Quilon (unpublished) and recorded a rich Burdigalian faunal assemblage between 30 to 120 metres, including *Clavulinoides* sp., *Triloculina* sp., *Nodosaria* sp., *Elphidium indicum, Sorites* sp., *Bolivina* sp., *Globigerina* sp., *Planorbulinella* sp., *Miogypsina antillea, Krithe autochthona, Cythereis* sp., *Aurila chaasraensis, Neomonoceratina* sp. and *Paijenborchella* sp., in addition to the forms reported by Jacob and Sastri (1952), and correlated it with that of Kutch.

Baripada Beds of Orissa, have been referred to as equivalent of Gaj Beds by Krishnan (1960) on the basis of *Ostrea gajensis*. A boring at Baripada through about 45 metres of these rocks, has revealed several fossiliferous beds, especially one layer full of *Rotalia* at the depth of 43.3 metres. The authors have also examined the material from Baripada Beds from the exposures near Baripada and have recovered abundant *Ammonia papillosus* along with *Cibicides, Elphidium* and *Nonion* sp. The authors did not see the type material mentioned by Krishnan, obtained from the bore hole near Baripada, but are inclined to believe that the *Ammonia papillosus* might have been identified as *Rotalia*. The fauna compares with that of the Cambay region, but it is probable that this part of the Baripada beds may be equivalent to the upper 110 metres of the Burdigalian sequence encountered in the Karikal region, where abundant occurrence of *Ammonia pappilosus* has been noticed and the typical Burdigalian forms are conspicuously absent. It is thought that at the lower horizons at Baripada also a characteristic Burdigalian fauna may be present as encountered in Sind-Baluchistan, Kutch, Karikal and Quilon areas.

The Miocene sequence met with in the Bengal Basin has been recognised under five mappable formal rock units (Biswas, 1963). The Burdwan Formation, barren of foraminifera except for local occurrences of estuarine and brachyhaline foraminifera, contains abundant spore-pollen, suggesting Oligocene to Lower-Middle Miocene age. It is overlain by the Pandua Formation (shelf occurrences) of Bhagirathi group towards the updip side. The few referred index foraminiferal species do not allow any close correlation, but provide certain evidences for the existence of more or less similar depositional conditions at Karikal and Bengal Basin. The overlying Debagram Formation and the contemporaneous geosynclinal trough development towards downdip, namely, Malta Formation and Ranaghat Formation, range in age from Middle Miocene to lower part of Pliestocene. The Post-Miocene, Neogene sequence at Karikal, referred to the "Karikal Beds", contain only fragmentary gastropods, limit the mutual correlation.

Sastri & Bedi (1962), reported a rich foraminiferal, Burdigalian fauna from Long, Strait & Nicholson Islands, including *Miogypsina* cf. *irregularis*, *Cycloclypeus*, *Neophrolepidina*, *Orbulina universa* etc. Chatterjee (1964) has assigned an Aquitanian age to this assemblage from the lower arenaceous zone of Archipelago series of Andaman Islands. The middle Argillaceous zone and the upper Interview Island stage in Archipelago series containing *Orbulina universa*, *O. bilobata*, *Globorotalia menardi*, *Globigerinoides gomitulus*, *L.* (*Nephrolepidina*) *sumatrensis* and *Operculinoides niasi* have been assigned the Burdigalian age. Sastri & Bedi (1962) gave a passing reference about the occurrence of rich *Orbulina* bearing *Globigerina* marl from Long & Nicholson Islands, but did not mention about its relative stratigraphic position. The fauna under discussion is dominated by the planktonic constituents and the typical Burdigalian forams as present in Western India and Karikal are practically wanted, except for *Miogypsina*, *Lepidocyclina* and *Orbulina*.

The equivalents of Lower Miocene in Ceylon are Jaffna & Kudremalai series occurring at NW coast of Ceylon. The fauna described includes *Orbiculina malabarica*, *Operculina* sp., *Flosculinella* sp., *Miliolids*, etc. and lacks the characteristic Burdigalian fauna of Karikal region.

It is interesting to note that Cossmann recorded a rich marine fauna mainly comprising of gastropods and unhesitatingly referred it to Pliocene. He examined the samples from a bore hole at Karikal, at a depth of 106 metres. The authors in the present study, have also obtained fragmentary gastropod fauna in the upper 70 metres, which may correspond to the "Karikal Beds" referred by Cossmann.

The Cuddalore Sandstones rest on the Pre-Cambrian at Cuddalore and on Cretaceous—Eocene beds near Pondicherry. Furon (1943) believed Cuddalore Sandstones to be equivalent to the "Pontian-Pliocene" Irrawaddy system of Burma, more particularly Pliocene as far as *Mesembryoxylon* (*Peuce*) *schmidianum* (Schieiden), a fossil wood was concerned. He regarded the rich marine Karikal fauna as a local development of the upper part of the Cuddalore Sandstones. Eames (1950) suggests that if the species of *Crocuta* (mammal), recorded by C. R. N. Rao, really did come from the Cuddalore Sandstones then part, at any rate, of the Cuddalore Sandstones is of considerably younger age than Pliocene and opines that the Pliocene "Karikal Beds" actually seem to be overlain by the Cuddalore Sandstones. If the uppermost 70 metres of the sequence in the present well, does correspond to the Pliocene "Karikal Beds" the current study reveals, these Beds do overlie the Lower Miocene (Burdigalian) sequence. The authors agree with Cossmann and Eames and support the Pliocene age of the "Karikal Beds".

Ramanujam (1953) suggested an upper Miocene age for the Cuddalore Sandstones on the basis of the plant remains. Even now the stratigraphical relationship of the Cuddalore Sandstones with the "Karikal Beds" is uncertain. The present authors do not agree with the suggestions and hypothesis put forward by Furon and Eames. Nowhere, the Cuddalore Sandstones are seen overlying the Karikal Beds and Eames (1950) based his conclusions on *Crocuta*, recorded from the beds at Sendurai, which have been referred doubtfully to the Cuddalore Sandstones. Recalling the stratigraphic evidences available and considering the data obtained so far by various workers, the authors are of the view that these Sandstones do not overlie the Karikal Beds, but are the equivalents to the Neogene sequence met with in the Karikal region. It is not unlikely to have comparatively still younger beds in the Cuddalore Sandstones near the top.

PALEO-ECOLOGY

The sea inundated the region some time during the early Tertiary period as evidenced by the deposition of the Alveolines and arenaceous foraminifera bearing basal 90 metres of the sediments, above the basement. The marked dominance of the planktons in the overlying Middle Eocene sediments generally circumscribes the deeper waters and suggests that this zone is correlative with the upper bathyal and outer shelf zone (Bandy 1960). The presence of *Globigerina bulloides* is indicative of eurythermal waters (Polski 1959, and Bradshaw 1959). The abundance of arenaceous foraminifera and *Uvigerina jacksonensis* in the upper part, suggests the shallowing of the basin corresponding to the central and outer shelf zone. Certain evidences favour the complete regression of the sea from the region at the close of the Paleogene period. The basal Neogene sequence comprising of poorly fossiliferous sandstones and sands is suggestive of near shore deposition. The abundance of *Spiroclypeus ranjanae* and *Miocyprideis chaudhuryi* in the Aquitanian sediments indicates shallow-marine-warm waters, comparable to the inner shelf zone. The greater availability of food in the photic and disphotic zones on the continental shelf both on the bottom and in the overlying waters is suggested by the large size attained by *Spiroclypeus ranjanae*. The bathymetric conditions throughout the Aquitanian and Burdigalian period remained more or less similar with minor fluctuations intermittently from inner to outer shelf zones.

The Burdigalian microfauna is dominated by Miliolids, Asterigerinids, Miogypsinoids and Lepidocyclines, in general and as such indicate the inner to central shelf zones of stable salinity. The relative paucity of the Peneroplids (*Taberina malabarica*) in the lower part and their absence in the upper part of the Burdigalian, indicates a comparative increase in turbidity towards the upper part. The occurrence of *Alveolinella* towards the upper part is of special interest. Bandy (1960) mentions, "A unique modern isomorph of the fusulinid foraminifera, of the later paleozoic is the genus *Alveolinella*, a spindle shaped genus that abounds in depths of 20 to 80 metres in the region of water......". *Ammonia papillosus* floods the assemblage in the upper 110 metres of the Burdigalian sequence, suggests the eurythermal waters of the inner shelf zone,

CONC USION

The Cretaceous sediments outcropping north and northwest of Karikal region could not be encountered in this well. The Middle to Upper Eocene sediments are richly fossiliferous and characteristically contain *Uvigerina jacksonensis*, *Halkyardia minima*, *Hantkenina* (*Applinella*) *dumblei*, *H.* (*Aragonella*) *lehneri*, *Globorotalia aragonensis* etc. No index Oligocene species could be recorded in the present well, but the existence of Oligocene sediments is not ruled out. The Lower Miocene sediments have rich faunas, mainly dominated by benthos and could be divided into Aquitanian and Burdigalian.

The fragmentary gastropod fauna obtained from the Upper 70 metres might correspond to the "Karikal Beds", referred by Cossmann. The Cuddalore Sandstones have been considered as homotaxial with the marine Neogene sequence at least in part and they may be Miocene to Pliocene in age.

The Miocene marine transgression affected only fringes of the Coromandel coast. The extent of the Miocene trangression in Karikal region is proved by this well and its extension can reasonably be presumed below the alluvial cover towards north, northwest and west. In southwest, at Pattukkottai the extent of Miocene sea could be established by the second well, marking the possible south-western extent of the sea in the main land. The recent geophysical surveys conducted by the Commission reveal the presence of a gravity high between the two wells drilled at Pattukkottai. This indicates, that the basin topography of the region was responsible for the controlled transgression of the sea. This view is further supported by the fact that the Cretaceous outcrops are present around the Karikal region and yet the Eocene sediments embrace the basement in the present Karikal well. Probably the Karikal region was standing out in form of a ridge, during the Cretaceous sedimentation or if it was partly submerged, the thin layer of the Cretaceous sediments might have been eroded out before the Tertiary deposition came into existence.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the help received from their colleagues in the Palaeontology Laboratory, O. N. G. Commission. They are particularly indebted to Sri S. C. Gupta for his active help in sorting the microfauna. Much valuable advice was given by Dr. B. G. Deshpande, Director of Geology, M. C. Poddar, Deputy Director of Geology and Sri P. V. Dehradai, Suprintending Geologist, Laboratories. The authors are grateful to the management and staff of the Karikal Project, for providing the samples for study.

INDEX TO THE LOCALITIES

Anklesvar region 22°20′ – 22°40′ : 72°20′ — 73°
Baripada 21°57′ : 86°45′
Cambay region 22°15′ – 23°30′ : 72°20′ – 73°
Cuddalore 11°45′ 30″ : 79°46′
Kutch 23° – 24° : 68°30′ : 70°30′
Nicholson Island 12°10′ – 12°9′ : 92°59′ – 93°
Padappakara 8°59′ : 76°39′
Pattukottai 10°25′ : 79°19′
Sendurai 11°15′ : 79°10′
Strait Island 12°11′ – 12°13′ ; 92°57′ – 92°58′
Surat 21°10′ – 21°40′ : 72°40′ – 73°
Chavara 8°58′ : 76°32′
Karikal 10°55′ 40″ : 79°50′ 15″
Long Island 12°7′ – 12°26′ : 92°56′ - 92°58′
Pondicherry 11°56′ : 79°50′
Quilon 8°54′ : 76°36′
Sakthi-Bulangava 8°48′ : 76°42′
Tanjore 10°46′ 30″ : 79°08′ 30″

REFERENCES

Bandy, O. L. (1960) : General correlation of Foraminiferal structure with environment. Int. Geol. Cong., XXI session Norden, part-22. I.P.U. Copenhagen.

Bandy, O. L. (1961) : Distribution of foraminifera, radiolaria and diatoms in sediments of the gulf of California. Micropalaeon. Vol. 7. No. 1. pp. 1-26, pls. 1-6.

Bandy, O. L. (1963) : Cenozoic Planktonic Foraminiferal Zonation and Basinal development in Philippines, Bull. Amer. Assoc. Petrol. Geol., Vol. 47, pp. 1733-1745.

Bhatia, S. B. & Mandwal, N. K. (1957) : Smaller Foraminifera from the Agate Conglomerates (Burdigalian) of the Surat-Broach area, western India. Pal. Soc. India, Jour., Vol. 2, pp. 163-173, text-figs. A—C.

Biswas, B. (1963) : Results of Exploration for Petroleum in the western part of the Bengal basin. Proc. sec. symp. dev. Pet. res. Asia & Far East. Min. Res. dev. Ser. No. 18, Vol. 1, pp. 241-246.

Chatterjee, A. K. (1961) : The occurrence of *Lepidocyclina* in India, Micro-Paleon., Vol. 7, no. 4, pp. 421-438, pls. 1-4.

Chatterjee, A. K. (1964) : The Tertiary fauna of Andamans. Vol. abstract XXII Int. Geol. Cong. India, p. 113.

Cole, W. S. (1962) : Embryonic chambers and the subgenera of *Lepidocyclina*. Bull. Amer. Paleont., Vol. XLIV, No. 200, pp. 29-60.

Cole, W. S. (1963) : Tertiary larger foraminifera from Guam. U.S. Geol. Surv. prof. paper, 403-E, pp. E1-28, pls, 1-11.

Drooger, C. W. (1954) : Study of American *Miogypsinidae*. Acad. thesis utrechs (1952), *Miogypsina* in North Italy. Proc. kon. Ned. Ak. Wetensch, Ser. B, 57, pp. 227-249.

Drooger, C. W. (1960) : *Miogypsina* in North Western Germany. Ibid. Ser. B. 63, No. 1.

Eames, F. E. (1950) : On the age of certain upper Tertiary beds of peninsular India and Ceylon. Geological Magazine, Vol, LXXXVII, No. 4, pp. 20-52.

Henson, F. R. S (1950) : Middle Eastern Tertiary Peneroplidae (Foraminifera), with remarks on the phylogeny and Taxonomy of the Family.

Jacob, K. and Sastri, V. V. (1951) : The occurrence of *Austrotrillina* in the Quilon limestones, South India Science and Culture, Vol. 16, No. 7, pp. 326-327: fig. 1.

Jacob, K. and Sastri, V. V. (1952) : Miocene foraminifera from Chavara, near Quilon, Travancore, India. Geol. Survey, Rec., vol. 82, pt. 2, pp. 324-353, pls. 14-16 ; 1 chart.

Le Roy, E. Becker and A. N. Dusenbury Jr. (1958) : Mio-Oligocene (Aquitanian) Foraminifera from the Goajira Peninsula, Columbia. Cushman Found. Form Res. special publication, No. 4, pp. 1-48, pls. 1-7.

Loeblich, (Jr.) Alfred. R. & Collaborators. (1957) : Studies in Foraminifera U.S. Nat. Mus., Bull. 215.

Lubimova, P.S., Guha, D.K. & Madan Mohan (1960) : Ostracoda of Jurassic & Tertiary deposits from Kutch & Rajasthan (Jaisalmer) India. Bull. Geol. Min. Met. Soc., India No. 22.

Miller, D. N. (Junior) (1953) : Ecological study of the Foraminifera of Mason inlet, North Carolina. Contr. Cushman found. Foram. Res., Vol. 4, pp. 41-63, Pls. 7-10.

Parker, Frances L., Phleger, Ered B. and Pelrson, jean F. (1963) : Ecology of Foraminifera from San Antonic Bay and Environs, Southwest Texas. Ibid. Pub., No. 2, pp. 1-74, pls. 1-3.

Sastri, V. V. & Bedi, T. S. (1962) : On the occurrence of *Miogypsina Cycloclypeus* and *Orbulina* in the Miocene of Andaman Islands. Current Science, Vol, 31, no. 1, pp. 20-21.

Tewari, B. S. (1956) : The genus *Spiroclypeus* from Kutch, Western India. Current Science, vol. 25, pp. 319-320, figs. 1-4,

Tewari, B. S. (1996) : The Genus *Halkyardia* from Kutch, Western India. journ Pal. Soc. India, vol. 1, no. 1, pp. 172-175, figs. 1-9.

EXPLANATION OF PLATE 1

1. *Textularia* sp. Burdigalian. × 44. front view.
2 *Biloculina* sp. Burdigalian. × 60. Side view.
3. *Spirosignoilina* sp. Burdigalian. × 60. Side view.
4. *Quinqueloculina* sp. Burdigalian. × 45. Side view.
5. *Quinqueloculina* sp. Burdigalian. × 23. Side view,
6. *Spiroloculina* sp. Burdigalian. × 24. Side view.
7. *Nummuloculina* sp. Burdigalian. × 35. Side view.
8. *Nodosaria* sp. Burdigalian. × 65. Side view.
9. *Guttulina* sp. Burdigalian. × 40. Side view.
10. *Nonion* sp. Burdigalian. × 55. Side view.
11. *Elphidium indicum*. Cushman. Burdigalian. × 30. Side view.
12. *Elphidium* sp. Burdigalian. × 70. Side view.
13. *Elphidium* sp. Burdigalian. × 74. Side view.
14 *Bifarina* sp. Aquitanian. × 40. Side view.
15. *Suggrunda* sp. Burdigalian. × 60. Side view.
16. *Reussella* sp. Burdigalian. × 36. Side view.
17. *Bolivina* sp. Aquitanian. × 63. Side view.
18. *Bolivina* sp. Burdigalian. × 33. Side view.
19. *Tubulogenerina* sp. Aquitanian. × 83. Side view.
20. *Discorbis* sp. Burdigalian. × 47. a. dorsal view, b. ventral view.
21. *Ammonia papillosus* Brady. Burdigalian. a, dorsal view × 26; b, ventral view × 25.
22. *Rotorbinella* sp. Burdigalian. a, dorsal view × 30 ; b, ventral view × 26.
23. *Amphistegina* sp. Burdigalian. × 63. dorsal view.
24. *Asterigerina* sp. Burdigalian. × 43. dorsal view.
25. *Globigerinoides triloba triloba* (Reuss). Burdigalian. × 67. a, dorsal view ; b, ventral view and c, side view.
26. *Asterigerina* sp. Burdigalian. × 36. dorsal view.
27. *Globorotalia mayeri* Cushman & Ellisor. Aquitanian. × 67. a, dorsal view ; b, ventral view and c, aperture view.
28. *Globigerina* sp. Aquitanian. × 88. dorsal view.
29. *Anomalina* sp. Aquitanian. × 82. side view.
30. *Cibicides mckannai* Galloway and Wissler. Burdigalian. × 30. ventral view.
31. *Gypsina globulus* (Reuss). Burdigalian. × 25. side view.
32. *Planorbulinella* sp. Burdigalian. × 65. side view.
33. *Cassigerinella chipolensis* Cushman & Ponton. Aquitanian × 93. side view. (sketch).

EXPLANATION OF PLATE 2

1. *Spiroclypeus ranjanae* Tewari. Aquitanian. × 16. a, exterior ; b, equitorial section.
2. *Lepidocyclina* (*Nephrolepidina*) sp. Burdigalian. × 10. Exterior.

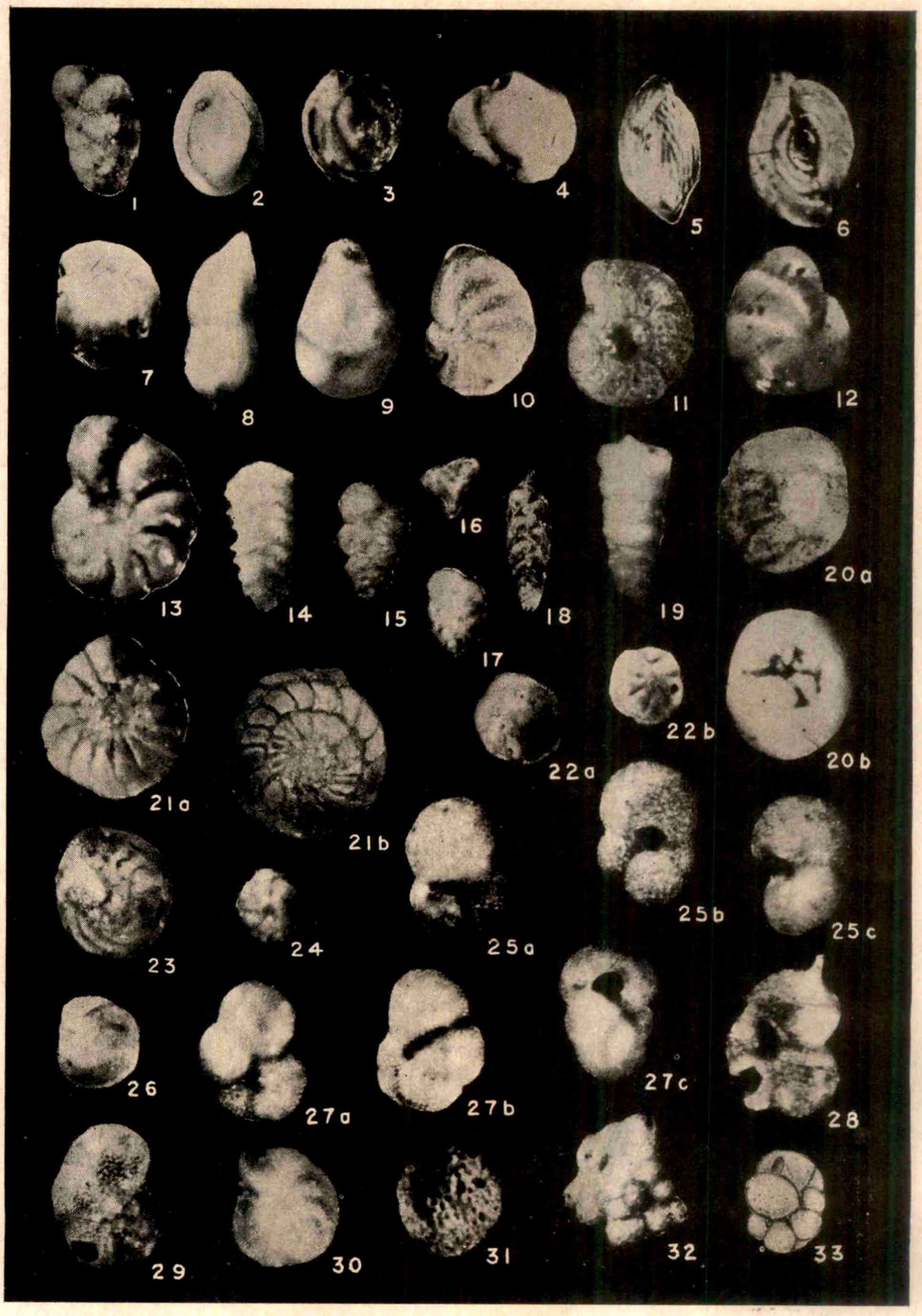

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20a
21a
21b
22a
22b
20b
23
24
25a
25b
25c
26
27a
27b
27c
28
29
30
31
32
33

PLATE 1

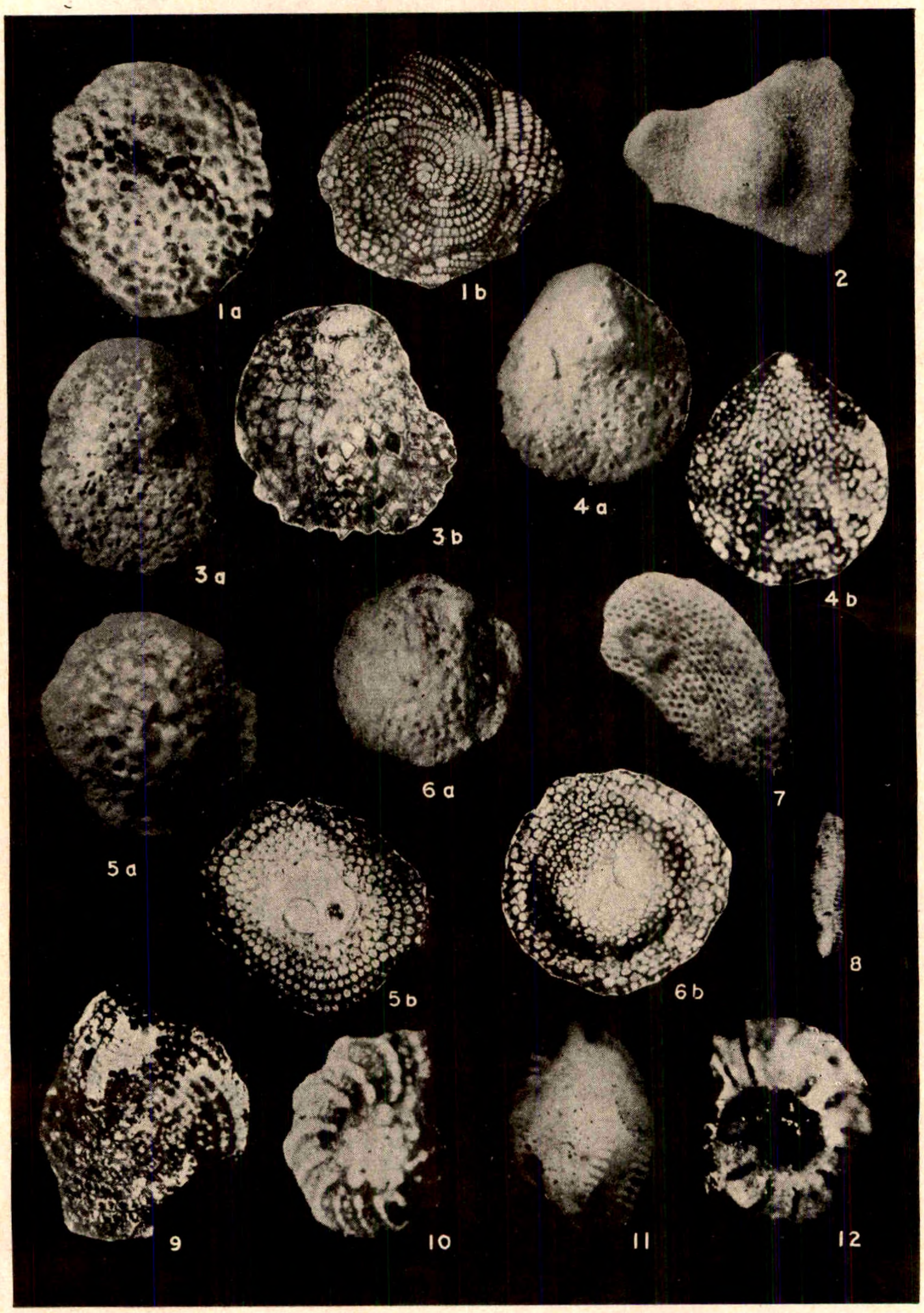


PLATE 2

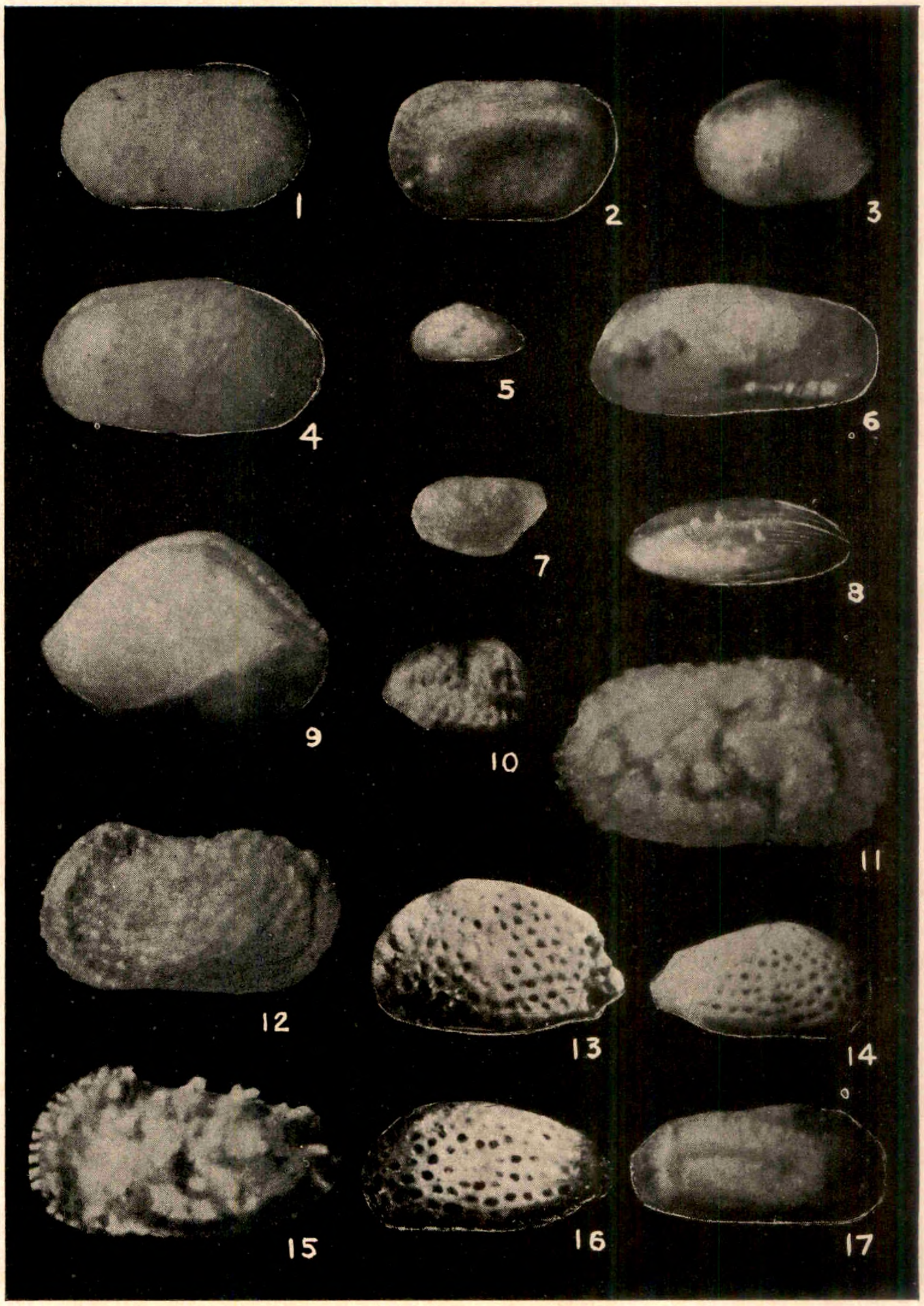


PLATE 3

3. *Miogypsina antillea* Cole. Burdigalian. a, exterior × 15 ; b, Equitorial section × 16.
4. M. *panamensis* Cole. Burdigalian. a. exterior × 14 ; b, equitorial section × 15.
5. *Lepidocyclina* (*Nephrolepidina*) sp. Burdigalian. a, Exterior × 15. b, Equitorial section × 15.
6. *Lepidocyclina* (*Nephrolepidina*) sp. Burdigalian. a, Exterior × 13 ; b, Equitorial section × 15.
7. *Sorites* sp. (Broken fragment) Burdigalian × 18.
8. *Allveolinella* sp. Burdigalian. × 10.
9. *Tabertina malabarica* (Carter). Burdigalian × 23, side view.
10. *Operculina* sp. Burdigalian. × 25. side view.
11. *Austrotrillina howchini* (Schlumberger), Burdigalian × 30. side view.
12. *Operculina* sp. Burdigalian. × 40. side view

EXPLANATION OF PLATE 3

1. *Cytherella protuberantis* Lubimova and Guha, Burdigalian. × 52, complete carapace, right valve view
2. *Cytherelloidea cutchensis* Lubimova & Mohan, Burdigalian. × 50. complete carapace. left valve view.
3. *Xestoliberis* sp. Burdigalian. × 40, complete carapace. left valve view.
4. *Miocyprideis chaudhuryi* Lubimova & Guha, Aquitanian. × 57. complete carapace. right valve view.
5. *Eucythere* sp. Aquitanian, × 38. complete carapace. left valve view.
6. *Krithe* sp. Burdigalian × 57. complete carapace. right valve view.
7. *Cytherura interposita* Lubimova & Guha, Burdigalian. × 28. complete carapace. left valve view.
8. *Argilloecia* sp. Burdigalian. × 55. complete carapace. dorsolateral view.
9. *Bairdoppilata poddari* Lubimova and Mohan. Burdigalian × 47, complete carapace. right valve view.
10. *Eucytherura* sp. Burdigalian. × 51. complete carapace. right valve view.
11. *Actinocythereis tumifacentis* (Lubimova and Guha) Burdigalian. × 50 complete carapace, right valve view.
12. *Echinocythereis fossularis* (Lubimova & Guha). Burdigalian. × 60. complete carapace. left valve view.
13. *Aurilla chasraensis* (Lubimova & Guha). Burdigalian. × 54 complete carapace. left valve view.
14. *Leguminocythereies mutata* (Lubimova & Guha), Burdigalian × 55, complete carapace. right valve view.
15. *Trachyleberis spinellosa* (Lubimova & Guha). Burdigalian × 53. exterior, left valve.
16. *Leguminocythereis mutata* (Lubimova & Guha). Burdigalian × 62. complete carapace. left valve view.
17. *Cytheretta trifurcata* Lubimova & Guha. Burdigalian × 54, complete carapace, right valve view.

CALCUTTA UNIVERSITY
CENTRAL LIBRARY

BULLETIN
OF THE
Geological, Mining & Metallurgical
Society of India

NO. 35 DECEMBER, 1965

A New Classification of the Tertiary Rocks of Kutch, Wastern India*

By

S. K. Biswas †

ABSTRACT

Rocks akin to the marine Tertiary rocks of Sind-Baluchistan are exposed in the coastal strip of the peninsula of Kutch, Western India. A complete sequence of the Tertiary is found in this area. A full time-stratigraphic classification of these rocks has been lacking. In this paper a time rock classification is proposed for the first time following mainly the stratigraphic code recommended by the American Commission of Stratigraphic Nomenclature (APPG. 1961)

A complete and unique succession of marine Tertiary rocks is exposed in Sind-Baluchistan region. This area had been considered as the type area of the marine Tertiary rocks of India till the partition when it went under Pakistan. In the present Indian territory a complete sequence of Tertiary rocks from Palaeocene to Pliocene is exposed in Kutch area, south west of the Aravalli Range at the western border of India.

Wynne and Fedden (1872) mapped this area and were the first to classify these marine Tertiary rocks. In their classification they were mainly guided by the lithological and biological characters of these rocks. In this classification the litho-stratigraphic and bio-stratigraphic nomenclatures were mixed up and it did not represent a complete sequence of the Tertiary rocks of Kutch.

---

* Read on 10 12. 65. † Geologist (Sr.) Oil and Natural Gas Commission.

The views expressed in this paper are those of the author only and not necessarily of the organisation for which he is working.

Comparing with the fauna of Sind-Baluchistan rocks, they tried to correlate the Kutch rocks with the time-rock-units of the former area, though, their stratigraphic divisions were the lithologic groups. Therefore, the necessity for reclassification of these rocks became evident.

The detailed systematic mapping of the Tertiary rocks in this region were undertaken by the geologists of the Oil &' Natural Gas Commission since 1957. Poddar (1959 & 1963) reviewed and summarised the Tertiary Stratigraphy of Kutch giving a chronological description.

Kutch area can be considered as the type area for the marine Tertiary rocks of India as this is the only area where a complete sequence is found. A detailed time-stratigraphic classification of the Tertiary rocks of this area has been lacking so far. A new time stratigraphic classification is suggested here. The units are named according to the geographical names of the respective type areas. This new classification, its correlation with the standard Sind-Baluchistan rocks and a comparison with the so far published classification of Wynne and Fedden are shown in the accompanying table. The characteristic fauna and stratigraphic relationship of beds are also shown in the table.

The exposed thickness of the stratigraphic units are not much as the outcropping area is the marginal part of a basin. There are evidences that the beds thicken towards the deeper parts of the basin e. g. the offshore region and the graben basins of Banni and Rann of Kutch.

The Tertiary rocks of Kutch are exposed along the coastal belt of southern and western Kutch bordering the Mesozoic rocks which occupy more than three-fourth of the outcropping area of Kutch. These rocks also border the so called islands : Patcham, Khadir, Bela and Wagad highland. The Tertiary rocks form two broad structural noses—Naran Sarover nose and Vinjan nose, around the noses of the Mesozoic anticlines. The Tertiary rocks are best developed in the south-western Kutch in the area north and west of the village, Waior. The total exposed thickness of Tertiary rocks of Kutch does not exceed 3000 feet and the thickest section has been measured in the above area. These rocks were deposited under stable shelf condition in a slowly transgressing sea since the early Eocene time excepting a short regressive phase during the Oligocene. Their environment of deposition never exceeded the limits of neritic zone.

Madh series :

The type area of the rocks of this series is the well known village of Matanumadh (or Madh as called locally) in western Kutch. The outcrop pattern of these rocks is very irregular as it follows the post-trappean topography. The series consists of a distinctive type of volcano-clastic sediments deposited in varied enviroments ranging from fluviatile to littoral. The clastics of these sediments were mainly derived from the Deccan Traps and the volcanic materials must have been derived from the finer pyroclastics ejected during the waning phase of the Trap vulcanicity.

This series is readily distinguished in the field by its colourful outcrops and characteristic lithology consisting of tuffs, volcanic ash, tuffaceous shales and sandstones and bentonitic clays. The lithology is extremely variable.

These rocks have yielded well preserved dicot leaf impressions and spores, pollens which are common in Lower Eocene. The age of the Deccan Trap is believed to be Upper Cretaceous to Lower Eocene. The Madh series overlies the Deccan Traps but underlies the Kakdi Stage which correlates well with the Lower Eocene Laki rocks. Thus, considering the order of superposition these rocks are assigned to the Palaeocene, while the age of the Deccan Traps in Kutch appears to be upper Cretaceous to Palaeocene. Further, the rocks of the Madh series from the type area of Matanumadh have yielded *Deltoidospora diaphana, Proteacidites palisadus, Ginkgo bilobaeformis, Schizea penicillata, and Verunonacolpites brevicolpatus.* These indicate a probable Palaeocene age for the Madh series (Y. K. Mathur, ONGC, by personal communication). In Sind-Baluchistan, Ranikot rocks lie over the Danian Cardita beaumonti Beds and underlie the Laki rocks. If the orders of superposition of beds in both the areas are compared then the uppermost Cretaceous, C. beaumonti Beds, corresponds to Deccan Trap of Kutch and Lower Ranikot to the Madh Series.

Berwali Series :

The type section is exposed along the Berwali Nadi in south western Kutch between the villages of Baranda and Ber Nana. This series is divisible into two stages—(1) the lower consists of gypseous and ochreous clays and marls containing Assilina granulosa and varieties of molluscs, well exposed in Kakdi Nadi section, and (2) the upper, well exposed in Babia hill in western Kutch, consists of dense fossiliferous fragmental limestones with a basal calcareous clay bed and contains numerous distinctive fossil zones. They are named accordingly. The Kakdi stage shows a littoral environment of deposition locally developing lagoonal environment. In the latter environment they show the development of euxinic facies – black shales with bands of lignite, bitumen, resin and sulphurous and pyritous shales. Such rocks are seen near Jhulrai and Madh. The Babia stage shows epineritic to neritic environments of deposition.

The base of Kakdi stage is marked by an unconformity above which occur highly gypsiferous shales with red ochre concretions and fossiliferous marls in contrast with the underlying volcano-clastic rocks of the Madh Series. The top of this stage is also marked by a disconformity above the grey barren shales capped by a red laterite band occuring below the calcareous nummulitic clay of the Babia stage. South of Baranda this contact is well exposed. It is difficult to recognise the top of the Babia stage in the field as it forms a part of one rock unit. The contact with the overlying series can roughly be fixed on the top of the dense, massive limestone above which occurs banded impure limestone with a basal bouldery marl of the Lakhpat series.

The Kakdi stage is correleted with the lower Eocene Laki series on the basis of the occurrence of the zone fossil Assilina granulosa, The Babia stage starts with a Nummulites obtusus band which ties it with the lower Kirthars and the overlying rocks correspond to the middle and upper Kirthars with the typical foraminiferal assemblages of middle and upper Eocene such as, *Nummulites sp.*, *Discocyclina sp.*, *Alveolina sp.*, *Dictyoconoides sp.*, *Lockhartia sp.*, *Halkyardia sp.*, and etc.

Lakhpat Series :

This series is well exposed in a continuous belt south of Lakhpat in north western Kutch. Lakhpat being the nearest important locality this series has been named after it. This series consists of greenish grey marls and argillaceous limestones with basal bouldery clayey marl bed. These rocks were deposited in an epineritic environment of a slowly regressing sea,

While the base is marked by the bouldery marl, the top is marked by the appearance of the basal oolitic band of the Waior Stage described below.

These beds contain typical Oligocene reticulate Nummulites. They are thus correlatable with the Nari series of Sind-Baluchistan.

Khari Series :

The series is named after Khari river in south western Kutch where this is well exposed in the high cliffy banks of the river. The series consists of two different stages distinguishable by both lithologic and biologic characters. The lowest stage, composed of banded fossiliferous marls containing Aquitanian forms, has been named as Waior stage as they are well exposed in the stream sections near Waior on south western Kutch. The upper stage consists of two lithologically distinctive parts. Both are well exposed in Khari river section between Jangadia and Chhasra and therefore the same name has been given to the stage also. The lower Khari stage is composed of very typical variegated siltstones, lower fifty feet of which is barren and upper part contains lower Burdigalian fossil assemblage. The upper Khari stage forms the bulk of the lower Miocene of Kutch and consists of grey to khaki coloured gypseous clays with hard marl bands packed with fossils. The clay contains rich assemblage of upper Burdigalian fossils.

The Khari rocks were deposited in a transgressing sea under tranquil condition. The depositional environment was epineritic to neritic. These are seen at places to rest on the Mesozoic rocks overlapping the Deccan Traps. This indicates the penetration of the Miocene sea much further inland. Thus the

Miocene transgression seems to be the most powerful one in the history of the Tertiary sedimentation. The barren fifty feet zone at the base of lower Khari substage probably indicates a break between the Oligo-Aquitanian regression and Burdigalian transgression.

The base of the Waior Stage is marked by a fossiliferous rusty brown ferruginous marl band, often oolitic. The top most marl band marks the upper limit of the stage above which the variegated siltstones of the lower Khari Stage occur. At the base of these siltstones occurs thick grey clay bed with molluscs. The top of the Khari stage is seen only in the Kankawati river section which is the type area for the overlying series. It is marked by a plane of disconformity separating the thick clay bed with fossiliferous marl bands of Khari series and the sandstones of the Kankawati Series.

Spiroclypeus-Miogypsina assemblage assigns an Aquitanian age to the Waior Stage. The lower Khari stage contains Turritella, Ostrea, Lepidocylina, Miogypsina assemblage. The upper Khari stage shows a rich assemblage of fossils with varieties of corals, gastropods, echinoids, lamellibranchs, foraminifers and ostracods. *Breynia carinata, Ostrea gajensis, Lepidocyclina sp., Operculina sp., Archais sp.*, etc. are the typical fossils. These assemblages show Burdigalian age for Khari stage and they are identical with the lower Miocene (Gaj Series) of Sind-Baluchistan. The Aquitanian Waior stage probably represents the lowermost Gaj series.

Kankawati Series :

Well exposed around Kankawati river section between Sandhan and Vinjan, this series consists of grey micaceous and calcareous sandstones, lenticular conglomerates and khaki grey clay. The upper part is mainly pinkish, hard, calcareous grits and conglomerates containing abundant foraminifers. These beds represent typical beach and deltaic deposits in a shallow sea. Fossil woods are common in the sandstones. A new species Dipterocarpoxylon malavii has been described by Ghosh (1959) from these rocks. Fossils of these rocks differ from the underlying Khari rocks and they are tentatively assigned to the Pliocene age and probably correlatable with the Manchhar beds of Sind-Baluchistan.

The (?) Pleistocene rocks, exposed in a few localities like Katrol hills and Wagad region, consists of calcareous, locally oolitic, sandstones containing foraminifers of Miliolidae family. They are similar to the so called 'Miliolidae rocks' of Saurashtra. The type area being the Porbander area of Saurashtra, they are named as Porbander series. These are mainly eolian deposits. The Pleistocene age has been tentatively assigned to these rocks. They may be even sub-recent in age.

Stratigraphic Relationship :

The Madh series rests disconformably over the Deccan traps. Its outcrop uniformly marks the limit of the Tertiary sea along the bordering landmass of

Deccan Trap hills. The Kakdi stage overlies the Madh rocks with an unconformity, followed by another disconformity between the Kakdi and Babia stage. The Babia stage, Lakhpat series and Waior stage form one rock unit but paraconformity has been observed between the last two stages and they form three different time units. The Khari stage occurs above the Waior stage with a transgressive onlap. The contact between Khari stage and the Kankawati series is marked by disconformit y

Acknowledgment :

The author gratefully acknowledges his indebtedness to Shri M. C. Poddar, Deputy Director of Geology, Oil & Natural Gas Commission, for his guidance in the present work. The author also acknowledges his thankfulness to his colleague Shri P. Mitra, Geologist, Oil & Natural Gas Commission, whose work and suggestions have been incorporated in this paper.

INDEX TO LOCALITIES

		Latitude			Longitude		
1.	Babia Hill	23°	42′	23″	68°	46′	10″
2.	Baranda	23	33	22	68	40	30
3.	Ber Nana	23	26	35	68	36	57
4.	Chhasra	23	21	00	68	48	47
5.	Jangadia	23	26	35	68	52	08
6.	Jhulrai	23	29	42	68	45	30
7.	Lakhpat	23	49	30	68	46	30
8.	Matano Madh (Madh)	23	32	37	68	57	00
9.	Sandhan	23	01	08	68	59	35
10.	Vinjan	23	06	23	69	01	30
11.	Waior	23	25	05	68	41	37

REFERENCES

Ghosh A. K. (1959) Science & Calture. Vol. 25, Nov. 1959, pp 328-332.

Krishnan M. S. (1956) Geology of India & Burma, 1956

Poddar M. C. (1959) Stratigraphy and Oil Possibility in Kutch, Western India. Proc. 1st. Sym. Dev. Petroleum Resources of Asia & Far East No. 10. pp. 146-148

——— (1963) Geology and Oil Possibilities of Tertiary rocks of Western India, Proc. 2nd Sym. Dev. Petroleum Resources of Asia and Far East, No. 18, pt, 1, pp 226-230.

Tewari B. S. (1956) The Genus *Halkyardia* from Kutch, Western India. Jour Palaeont Soc. India, Vol 1, p 175.

——— (1957) Geology and stratigraphy of the area between Waghapdar and Cheropadi, Kutch, W. India. Jour. Palaeont. Soc. India, Vol, 2 P. 136-148.

Wynne A. B. & Fedden F. W. (1872) The Geology of Cutch, Mem. G. S. I. Vol. IX Pt. I 1872.

"Code of Stratigraphic Nomenclature"-American Commission of stratigraphic Nomenclature, Bull. American Association of Petroleum Geologist, Vol. 45, No. 5, 1961, pp, 648-660

Definition of Geologic Systems, International Subcommission on stratigraphic Terminology, Int. Geol. Cong. Part XVIII, 1964,

PHY OF KUTCH

Fauna		Sedimentary facies & environment. Tectonic Environment-stable shelf.	Wynne & Fedden 1872	Sind-Baluchistan standard Section
	Others			
		Mostly arenaceous facies. Restricted marine, arid, fluviolacustrine, Eolian.		
		Arenaceous facies. Fluvial & eolian.		
		Sand & Carbonate facies. Eolian.	Miliolite Limestone. (Porbandar stones)	
lo- p, li- on ium	*Balanus* (?) sp. *Ostrea* sp. Plants—Dipterocarpoxylon malavii, Tricolpate pollens.	Mostly sand facies with minor shales and carbonate rocks. Transitional environment—Estuarine deltaic.	Up. Tertiary	Manchhar Series
i, ido- s eri- . nsis,	Ostrea latimarginata, O. Angulata, Breynia carinata, Clypeaster sp. Turritella and other gastropods, corals, bryozoa, Crabs and fossil algae.	Clay, Silt & marl facies. Epineritic to neritic environment.	Argillaceous Group. Arenaceous Group.	Gaj Series
t es na		Marl facies, Epineritic, environment.	Nummulitic limestones.	
ts, s, sp. ppi-	Varieties of Gastopods and lamellibranchs.	Arenaceous marl facies Epineretic environment.		Nari Series.
ti, a na	Ostrea sp., and other mollusca, varieties of echinoids Corals, crabs and gastropods.	Fossiliferous fragmental limestone facies, clay facies in the lower part. Epineritic environment of deposition.		Kirthar Series.

TERTIARY STRATIGRA

Epoch	Series	Stage	Lithology	Foraminifera
Recent			Rann, Alluvium, Blown sand etc.	
Sub-Recent			Conglomerates, Grits, Kankars etc.	
			Unconformity	
Pleistocene	Porbandar Series 50 ft. (+) (15m.)		Oolitic calcareous sandstones.	Species of the family Miliolidae.
			Unconformity	
(?) Pliocene	Kankawati Series 1200 ft. (+) (365m.)		Grey sandstone, pink fossiliferous calc. grits, and conglomerates.	Textularia sp., Quinqu culina sp., Triloculina Biloculina sp., Spiroloc na sp., Lagena sp., Non sp., Rotalia sp., Elphi sp. & etc.
			Disconformity	
Miocene	Khari Series 1150 ft. (350m.)	Khari stage 1120 ft. (341m)	Upper: 900′ (275 m.) Grey and khaki clay with fossiliferous marls. Lower: 220′ (66 m.) Variegated siltstones.	Austrotrillina howchi Taberina malabarica. Archaias angulatus, Le semicyclina sp., Sorit sp., Operculina sp. As gerina sp. Elphidium s Cytherelloidea kutch Miogypsina, and etc.
				Unconformity
		Waior stage 30 ft. (9 m.)	Banded cream coloured fossiliferous marls and ferruginous oolites.	Spiroclypeus ranjanae other sp. Miogypsinoic dehaarti, Nephrolepidi sp. Bairdoppilata sp. Anomalinella sp.
			Para-conformity	
Oligocene	Lakhpat Series 40 ft. (12 m.)		Dirty white & yellow banded marl and impure limestone.	Nummulites intermedi N. clipeus, N. subclipe Operculina sp., Rotali Asterigerina sp., Baird lata poddari and etc.
Eocene	Berwali Series 430 ft. (130 m.)	Babia stage 280 ft. (85 m.)	Upper: 200′ (60 m.) Cream and buff massive limestone, packed with fossils. Lower: 80′ (25 m.) Greenish grey fossiliferous calcareous clays.	Nummulites acutus, N, stamineus, N. beaumor N. Obtusus, Assilina exponens, Discocyclina dispansa, Discocyclina javana, Discocyclina sowerbyi, Actinocycli kutchensis, Asterocycl alticostata, Alveolina